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PHYSICS.—*The skeptical physicist.*[1] PAUL R. HEYL, National Bureau of Standards.

Those of you who are acquainted with the history of science will recognize the source whence I have plagiarized the title of this address. In the middle of the 17th century the young science of chemistry was in a state which troubled the conscience of the Honorable Robert Boyle, whose interest in this science was life-long. There was a theory widely held at that time that all substances were composed of three primary principles—salt, sulphur and mercury. In "The Sceptical Chymist," published in 1661, Boyle combated this idea, criticizing the experiments upon which it was based, and pointing out among other things the difference between mixtures and compounds. Modern chemistry owes much to the pioneer work of Boyle, and his merits were not unappreciated by his contemporaries, who dubbed him "the father of chemistry and the brother of the Earl of Cork."

The term "skeptical" has an etymology from which its present-day meaning has widely departed. The Greeks applied the adjective σκεπτικός to a person who gave thoughtful consideration to matters which called for action or decision. The antithesis of such a skeptic was the person who acted on impulse or emotion. Perhaps because the judgment of the skeptic was so often adverse, he gradually became recognized as a chronic doubter or even as an iconoclast. It is possible, however, that these adverse opinions may have been due in many cases not to original sin in the skeptic, but to essential unsoundness in the subjects that he was called on to consider.

I like to think that Boyle used the term "skeptical" in its original sense, and in that sense I may be permitted to use it in the present discussion. It is as true now as when Victor Cousin said it, nearly a century ago, that "la critique est la vie de la science," and the history of science shows that situations arise at frequent intervals where the application of this principle is called for. When criticism is stifled, science is dead.

[1] Address before the Philosophical Society of Washington on December 18, 1937. Received January 12, 1938.

One of these situations confronts us at the present time, and has called forth a protest from a skeptical physicist to which scientific men of all households of faith may well give attention, for though it is the science of physics that is immediately concerned, the situation involves the fundamental question of the attitude of the scientific man toward Nature.

I refer to Dr. Herbert Dingle and his article on "Modern Aristotelianism" which appears in *Nature*, May 8, 1937. The replies, pro and con, to this article were so numerous and extensive that it was necessary to devote an entire supplement of *Nature* to them (June 12, 1937). It will, I think, be interesting and profitable to give a resumé of Dingle's article and of some of the replies to it.

Dingle's article may appear to have been inspired by published statements by Eddington and Milne, but between the lines there are some of us who can read sympathetically the story of a slowly growing skepticism which has finally burst all bounds.

The term "Aristotelianism," as Dingle uses it, does not refer so much to the doings and thinkings of Aristotle himself as to the habit of mind and the outlook upon Nature of the medieval scholars who acknowledged the great Stagirite as their master. Orthodox science since Galileo's day has held that the first step in the study of Nature is the observation of phenomena, from which we may pass by induction to the derivation of general principles. The "Aristotelianism" to which Dingle refers, and which dominated the scholastic thought of the western world up to the 17th century, was the doctrine that there are general principles known *a priori* to the human mind apart from observation or sense perception.

For instance, Aristotle reasoned that a heavy body must fall more rapidly than a lighter one, and this *a priori* principle was accepted and believed by the Aristotelians for 2000 years, until it was shown by experiment and observation that such was not the fact. As Emerson says, "Things are in the saddle, and ride mankind."

For three centuries this Aristotelian view of Nature has been regarded, at least by scientific men, as dead. It is therefore, as Dingle says, no light matter when we find in our own day a revival of Aristotelianism in the front ranks of science itself. As ground for this serious charge Dingle quotes statements by Eddington and by Milne.

Eddington[2] says, "There is nothing in the whole system of laws of physics that cannot be deduced unambiguously from epistemological

[2] "Relativity Theory of Protons and Electrons," p. 327.

considerations. An intelligence unacquainted with our universe, but acquainted with the system of thought by which the human mind interprets to itself the content of its sensory experience, should be able to attain all the knowledge of physics that we have attained by experiment."

Milne[3] is somewhat more restrained and conservative when he says, "It is, in fact, possible to derive the laws of dynamics rationally . . . without recourse to experience."

Statements like these, coming from leaders in science, are indeed serious, and it will be interesting to see what their authors have to say in their own defense.

Eddington stands by his guns, remarking that the passage cited by Dingle has been likewise quoted "without its safeguards" by almost all the reviewers of his book. And what are these safeguards? Eddington makes it clear that the quoted passage must not be interpreted as the *a priori* basis of his philosophy, but is the unexpected conclusion at which he has arrived as the result of his investigations.

And what are these investigations?

Some years ago Eddington, by an abstruse mathematical discussion which he states did not involve any observational measurements, arrived at a figure for the mass-ratio of the proton and electron which was quite close to the accepted experimental results. Still later he calculated by relativistic-wave-mechanics method that the total number of elementary particles in the universe is $2\times136\times2^{256}$. This result still awaits experimental check.

"After a rather extensive series of researches," says Eddington in his reply to Dingle, "I have found that a great part of the current scheme of physics is deducible by *a priori* argument." But he goes on to admit that "since we can have no *a priori* knowledge of an objective universe such results do not constitute knowledge of an objective universe." Just what they do constitute he does not make clear.

Milne, in his defense, takes much the same position as Eddington. Dingle's criticism of Milne was directed in part against his doctrine of "kinematical relativity," which is a study of the consequences of the assumption that the universe is, on the average, homogeneous both in distribution and motion. In developing the consequences of this assumption Milne endeavored to avoid any empirical appeal, and to develop the physics of the universe after the manner of a logical geometry based upon axioms or space-definitions. In carrying out

[3] Proc. Roy. Soc., A, 158, 329; 1937.

this development Milne appears to have made the same discovery as Eddington. Milne remarks that it is an astonishing thing to find that the elimination of empirical appeal, including all appeals to quantitative laws of physics, can be carried as far as it can; and that with the elimination of such empirical appeals regularities emerge which play the part of the very laws of Nature which are observed to hold good.

Milne admits that his resulting logical structure may not correspond to Nature any more than do the various hypergeometries that have been invented, but says that just as results of value have followed from the development of such non-realizable abstractions as a four-dimensional cube, so it may be valuable to construct an abstract physics for its own sake.

This is a reasonable defense. As long as the limits of such investigations are clearly recognized, and they are held strictly within these limits, they may be as valuable and stimulating as any other scientific speculations. But the essence of Dingle's criticism is that this line of action can be carried to such excess and be given such a color as to deceive the very elect. When those to whom we look for scientific leadership can say, in effect, "Don't experiment; calculate! It is easier, cheaper, more exciting and productive of results," then science is on its way back to the Aristotelianism of the Middle Ages.

The ability of a theory to calculate and predict phenomena is an asset of undoubted importance, but it is not enough, and must not be over-rated. A modern instance of this is Bohr's theory of atomic structure. The flexibility and accuracy with which the Bohr atom adjusted itself to the manifold conditions required by the periodic law of the elements were remarkable. The Bohr theory moved along with regular steps, dropping the right element into each empty compartment provided by the periodic law. When it came to the rare earths the theory halted for a moment, dropped exactly the right number of elements all into the same compartment, and then resumed its measured tread, dropping one element at each step until all were put in their proper places. No wonder that Whetham characterized this behavior as "satanic." Yet with all this to its credit the Bohr atom, because of its failure to meet three requirements, had to give place to a still more adaptable theory as soon as one could be found.

The theory of relativity is in a similar position today. It has done much; it has explained one astronomical puzzle for which the Newtonian law of gravitation was inadequate; it has predicted two other physical phenomena whose existence has been experimentally verified; but when it comes to such a simple matter as centrifugal force,

then, as Eddington himself says, the theory stops explaining phenomena and begins explaining them away. The theory of relativity holds its own today only because no one has as yet been able to devise a better.

The failure of a theory for reasons of this character need reflect no discredit upon its author. We can still admire a theory which has marked a step in progress, which has been able to cut a little more closely to the line than any which preceded it, even though it be soon superseded by a better. But some theoretical researches in modern physics fall into a different category, and tend to make the skeptical physicist a little more skeptical.

These researches are for most of us difficult reading. Perhaps this is unavoidable, considering the nature of the subject. We of the rank and file must frequently take the results of our leaders on faith; and unfortunately we sometimes find in those portions which we can understand that which seriously shakes our confidence in the parts that we cannot follow. When, for example, Eddington[4] says that the mass of the sun is 1.47 kilometers, and repeats this in the second edition of his book, and when Minkowski[5] points with pride to what he calls "the mystic formula"

$$3\times10^5 \text{ km} = \sqrt{-1} \text{ sec},$$

and when it requires no knowledge of the calculus of tensors to see what the trouble is, the only conclusion possible is that the fundamental principles of mathematics and physics are like the laws of whist—for beginners to observe and for masters to disregard.

Minkowski's memoir on "Space and Time," in which this "mystic formula" occurs, has long enjoyed the reputation of a classic. It antedates Einstein's general theory of relativity by seven years, and in his paper of 1915 Einstein acknowledges his debt to Minkowski. Minkowski's memoir contains the concepts of the four-dimensional space-time continuum, of world lines and of space-like and time-like vectors upon which basis has been erected a vast structure of relativistic cosmology. With this "mystic formula" staring us in the face it will be interesting to examine the philosophical basis of Minkowski's theory.

The fundamental idea of the memoir is that time in some way bears

[4] Report on the Relativity Theory of Gravitation, second edition, 1920, p. 50.

[5] "Raum und Zeit," an address before the German Convention of Natural Scientists and Physicians, Cologne, Sept. 21, 1908. Phys. Zeitschrift, Vol. X, p. 104, 1900. English translation in "The Principle of Relativity; memoirs by Lorentz, Einstein, Minkowski and Weyl," New York, Dodd, Mead and Co., 1923.

a fourth-dimensional relation to our solid space. Now, of course, time has not the dimensions of a length, but if we multiply it by a velocity that defect disappears. Minkowski multiples the time t by the velocity of light c, thus obtaining the length ct which may be used as a fourth dimension. Unfortunately, it happens that an important equation resulting from this hypothesis is not symmetrical.

Now every mathematician has in him something of the artist; an eye for symmetry, for beauty of results and for elegance in the methods used in obtaining them. An unsymmetrical equation offends the artistic sense; in addition, it is scientifically undesirable, as results cannot be obtained from it as readily as from a symmetrical form. And here Minkowski had a brilliant idea. If we multiply the fourth dimension ct by $\sqrt{-1}$ the unsymmetrical equation becomes symmetrical.

Of course this gives us a set of four axes, three of which are real and one imaginary, but any difficulty attaching to this detail is soon forgotten in the dazzling light of the brilliant results that begin to appear. For example, referred to our new coordinates, the complicated Lorentz transformation appears as a mere rotation of the axes —which, however, involves the turning of the imaginary axis through an imaginary angle.[6] Whether this makes the Lorentz transformation any more comprehensible is a question—which the artist-mathematician answers in the affirmative.

$\sqrt{-1}$ has a legitimate application in pure mathematics, where it forms a part of various ingenious devices for handling otherwise intractable situations. It has also a limited value in mathematical physics, as in the theory of fluid motion, but here also only as an essential cog in a mathematical device. In these legitimate cases, having done its work it retires gracefully from the scene; but to make an imaginary quantity a permanent foundation stone for a physical hypothesis is, as they say in Ireland, a white horse of another color.

There is no denying the potency of $\sqrt{-1}$ as a useful tool. As an illustration, I may point out how it helps us to an interesting little theory of gravitation. Einstein, in discussing the resemblance between inertia and gravitation, considers the case of a revolving circular platform. Suppose such a disk large enough to hold an observer, and let it be covered by a dome so that the observer within cannot tell by direct observation of outside bodies whether the disk is in motion. Let the disk be at rest. The observer, in moving from one place to

[6] Minkowski discusses this point very briefly. The complete methematical treatment is given by Eddington in his "Report on the Relativity Theory of Gravitation," second edition, 1920, page 14.

another in his little world would notice no difference between one point and any other. Let the disk be now set in rotation. The observer, unless he stood at the center of the disk, would experience a force urging him radially outward, and the farther he was from the center the greater would be this force. He would, in fact, be living in a sort of turned-inside-out gravitational field.

As a theory of gravitation there are two defects in this. The force increases with the distance from the center; and it is in the wrong direction, outward instead of inward. The first of these defects is quite easy to remedy. We may suppose the speed of rotation of the disk to be variable, governed either by a mechanical device or by a watchful engineer so that the speed will increase as the observer approaches the center, and will diminish as he nears the circumference.

The other defect is not so easy to dispose of. It is obviously useless to give the disk a negative velocity of rotation, as the centrifugal force depends on the square of the velocity. But if we multiply the velocity not by -1 but by $\sqrt{-1}$, the trick is done.

Everybody laughs at this; nobody laughs at Minkowski. Yet I have done nothing but what Minkowski has done. I have turned my disk through an imaginary angle; Minkowski turned his axes of coordinates through an imaginary angle. The trouble is that I have made my illustration so simple that anyone can see through it. Had I made it as abstruse as Minkowski's memoir it might have been received with equal seriousness. Truly, as Dingle says, the criterion for distinguishing sense from nonsense has been lost; our minds are ready to tolerate anything, if it comes from a man of repute and is accompanied by an array of symbols in Clarendon type.

And yet we must not be too hard on $\sqrt{-1}$; it may stand us in good stead on occasion, as is instanced by a tradition of the National Bureau of Standards.

In the early days of the Bureau, when the staff was smaller, and there were no official guides, the staff-members took turns in conducting parties of visitors through the laboratories. On one such occasion the visitors were shown some liquid air, and they asked, "What is this used for?" In those days liquid air had not yet found any practical application, and was merely a scientific curiosity. The guide, who tradition says was one of the lady-members of the staff, was rather non-plussed for the moment, but quickly recovered her presence of mind, and replied, "It is used to lubricate the square root of minus one."

I sometimes think Minkowski must have heard that story.

CHEMISTRY.—*Biochemistry by analogy: the sulfur of cystine.*[1] BEN H. NICOLET, Bureau of Dairy Industry.

We are, I think, all agreed on the proper way to attack a chemical problem. One should set up a crucial experiment with the substances supposed to be concerned, carry the experiment to completion, and see what happens. But often, particularly in biochemistry, this is hard to do. It may be necessary to carry out an analogous reaction, under supposedly more or less analogous conditions. This is known as a "model" experiment, though it is very far from being a model of what one might wish to do. It frequently amounts to thinking what certain molecules *should* do, and trying to establish, a bit indirectly, whether such a reaction is really plausible. I shall talk to you this evening of "model" experiments, and I intend to see whether I can convince you of the value of the conclusions, as yet incompletely confirmed, which I shall draw from them.

Cystine (I) and methionine (II) are the two best known amino acids containing sulfur which go to make up proteins. Both are readily synthesized by plants, but with regard to animals (including outselves) both are essential amino acids—or nearly so.

An "essential" amino acid is one which must be supplied in the diet if an animal is to live and grow normally. In other words, the animal body cannot synthesize essential amino acids, or cannot do so in sufficient quantity. According to the latest data,[2] animals can not synthesize methionine under any known conditions. On the other hand, a cystine deficiency can be corrected either by cystine, methionine, or homocystine (III). It is, accordingly, at least very probable that animals *can* synthesize cystine, although only, so far as we yet know, when methionine or homocystine is fed. The problem tonight is, how cystine and methionine get their sulfur, and, in part, how they lose it again.

$2(\text{–SCH}_2\text{CH(NH}_2\text{)CO}_2\text{H})$ $\qquad$ $\text{CH}_3\text{SCH}_2\text{CH}_2\text{CH(NH}_2\text{)CO}_2\text{H}$

I $\qquad$ II

$2(\text{–SCH}_2\text{CH}_2\text{CH(NH}_2\text{)CO}_2\text{H})$

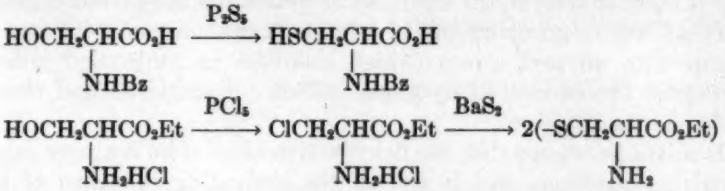
III

There are two syntheses of cystine on record. Erlenmeyer treated benzoylserine with phosphorus pentasulfide. Emil Fischer converted serine ester hydrochloride to β-chloroalanyl ester hydrochloride, and

[1] Address of retiring president, Chemical Society of Washington, January 13, 1938. Received January 28, 1938.

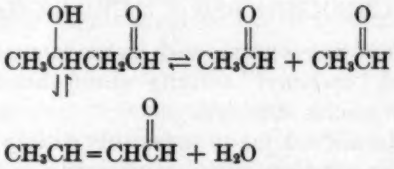
[2] Rose, Science 86: 298. 1937.

then allowed this to react with barium disulfide. Hydrolysis gave cysteine and cystine, respectively.

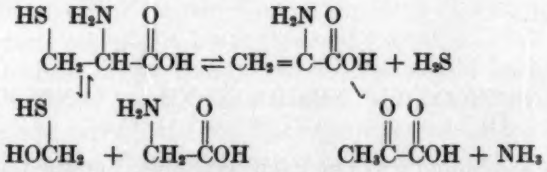


Surely neither of these syntheses approaches the possibility of being a biological synthesis.

A few years ago I talked to you once before[3,4] about cystine. I asked you then to recall the reactions of aldol formation and dehydration, and their reversals. It is particularly necessary to remember that *all* these reactions are reversible.



I presented to you at that time the idea that the desulfurization of cystine by alkali was essentially analogous to the dehydration of an aldol, and should obey the same rules, including reversibility. The work of Dr. H. T. Clarke[5] and his students on the hydrolysis of cystine was entirely in accord with the first part of this notion. It showed very clearly that the chief direction of cystine decomposition by alkali led to hydrogen sulfides, ammonia, and pyruvic acid. In the following equations cysteine is used, for simplicity of presentation, in place of cystine to show the formal analogy to the aldol reactions shown above. Under suitable conditions, reactions analogous to most of these types can be demonstrated.



[3] Nicolet, J. Am. Chem. Soc. **53**: 3066. 1931.
[4] Nicolet, J. Biol. Chem. **95**: 389. 1932.
[5] Clarke and others, J. Biol. Chem. **94**: 541. 1931. **102**: 171. 1933. **106**: 667. 1934.

At the same time, attention was called to the fact that modification of the cystine molecule in the direction of peptide formation, or, to put it more simply, in the direction of combining the carboxyl group with an amide grouping (as in peptide formation) and the amino group with an acyl group (which *could* be an aminoacyl group) *facilitated* the *removal* of hydrogen sulfide (or disulfide) and *should* facilitate its addition.

It might be argued that the dehydration of an aldol is a very easily occurring reaction, and is due to the activating influence of the aldehyde group. Cystine, on the other hand, offers considerable resistance to alkali; and it is well known that the –CO– grouping present in carboxyl, retains very little of the typical "carbonyl" properties. It was, however, shown quite definitely at that time that mercaptans add very readily to α,β-unsaturated ketones, such as benzalacetone.

$$PhCH=CHCOCH_3 + RSH \rightleftharpoons PhCH(SR)CH_2COCH_3$$

These products lose mercaptans with extreme ease. A quite small fraction of the full "carbonyl" activity would therefore be sufficient to account for the results obtained.

You will perhaps not ask me to repeat my earlier talk further. Let us assume that the reactions eliminating sulfur occur as suggested, and that they are reversible. The simplest reaction by which cystine (or cysteine) could be formed, would be the addition of hydrogen disulfide (or hydrogen sulfide) to α-aminoacrylic acid (IV), which we may also call dehydroalanine, since it represents the removal of two hydrogen atoms from alanine.

But we shall not expect to be able to demonstrate this reaction, as such, for two reasons. Aminoacrylic acid itself is so unstable that it has never been isolated. And, secondly, we should have much better hope of success if the carboxyl or amino group, or both, were suitably modified. What we should prefer would evidently be a peptide (V) (at least a tripeptide) in which the dehydroalanyl group was not at either end.

$$\underset{\text{IV}}{CH_2=C(NH_2)CO_2H} \qquad \underset{\text{V}}{NH_2CHR'CO-NH-\overset{\overset{CH_2}{\|}}{C}-CO-NHCHRCO_2H}$$

Such a compound was not itself available. For the tentative test, a compromise had to be made. The simplest known derivative of aminoacrylic acid is Bergmann's acetylaminoacrylic acid (VI). It

should not be expected to work very well, but it does work.

Heated for ten hours at 100° with benzyl mercaptan and a little piperidine as catalyst, it gave a small but definite yield of N-acetyl-S-benzylcysteine (VII). This was hydrolyzed to S-benzylcysteine (VIII).

$$CH_2{=}C(NHAc)CO_2H + PhCH_2SH \rightarrow PhCH_2SCH_2CH(NHAc)CO_2H$$

VI VII

$$PhCH_2SCH_2CH(NH_2)CO_2H \qquad HSCH_2CH(NH_2)CO_2H$$

VIII

Dr. Loring was kind enough to apply to this Dr. du Vigneaud's process of reduction by means of sodium in liquid ammonia, for the removal of the benzyl group from sulfur, and obtained a 93 per cent yield of cysteine, as shown by the specific Sullivan method.

This is a new synthesis of cysteine, and therefore of cystine. But certain other requirements must be met if it is to be considered as even a possible model for a biochemical synthesis of these amino acids.

Since a dehydroalanyl tripeptide such as V was not available, benzyl mercaptan was next added to benzoyldehydrophenylalanylglycine ester (IX). The resulting mercapto derivative (X) was formed some 50 or 100 times more readily, as estimated by the much better yield obtained in a much shorter time.

$$PhCH{=}C(NHCOCONHCH_2CO_2Et)Ph \qquad PhCH(SCH_2Ph)CONHCH(CONHCH_2CO_2Et)Ph$$

IX X

Now peptides containing alanine are very common. It is extremely probable that, in their metabolism, they pass, in the presence of suitable enzymes and of suitable hydrogen acceptors (or oxidizing agents), through the stage of dehydroalanine derivatives. I have tried to show elsewhere[6] that this dehydrogenation should take place more readily when the alanine was a component of a peptide chain, and particularly when it was not terminally located. Thus the most commonly formed dehydroalanyl derivatives should be just of the type most suitable for sulfide addition. We have thus acquired, through model experiments, the basis for a picture of the biological synthesis of cystine which is at least somewhat credible.

As a sort of parenthesis, it might well be remarked here that a

[6] Nicolet, Science 81: 181. 1935.

natural synthesis of serine should be based on just the same organic intermediates as the cystine synthesis. It is here merely a case of adding water, instead of sulfide.

Silk proteins contain much more serine than any others. They are also conspicuously richer in alanine than most other proteins, and therefore should offer a richer source of dehydroalanyl derivatives. This is not, I think an accident

I should now like to extend the ideas already advanced to the consideration of the biochemical synthesis of methionine. Only plants can make methionine, for Rose has found it an essential amino acid for animals.

The logical intermediate for its synthesis appears to be methylenepyruvic acid (XI). It is a well known fact that plants have at their disposal for synthetic purposes formaldehyde and pyruvic acid. The condensation of these to form methylenepyruvic acid would be most orthodox. Here again we meet a substance which has never been isolated, presumably on account of its considerable lability.

This is a hindrance to its use by a chemist, but not to its use by a plant. Formaldehyde has been condensed with pyruvic acid by various investigators, and under various conditions. The process has always gone too far, but in such a way as to indicate that methylenepyruvic acid, or possibly hydroxymethylpyruvic acid, which would perhaps serve equally well, has been an intermediate.

$$CH_2O + CH_3COCO_2H \rightleftharpoons \underset{\text{XI}}{CH_2{=}CHCOCO_2H} \rightleftharpoons$$

$$\underset{\text{XII}}{CH_2CH_2COCO_2H} \rightarrow \underset{\text{XIII}}{CH_2CH_2COCO_2H} \rightarrow CH_2CH_2CHCO_2H$$

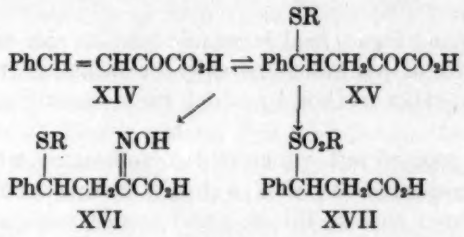
(SH on XII; SCH_3 on XIII; SCH_3 and NH_2 on the product)

Whether the addition reaction involves methylmercaptan, or hydrogen sulfide with subsequent methylation, is not at present considered. Plants, in contrast to animals, have a conspicuous capacity for such methylations.

Since the desired substance was not available, recourse was had to another model experiment. Benzalpyruvic acid (XIV) was found to add mercaptans[7] with the greatest ease, under the simplest conditions possible. With no added catalyst whatever, fairly quantitative addition was obtained in five minutes at 100°. It is considered that this is an obviously adequate rate of reaction to justify this stage of the

[7] Nicolet, J. Am. Chem. Soc. 57: 1098. 1935.

synthesis. It was further shown that the products had the structure indicated, since on oxidation they yielded the known β-sulfones of β-phenylpropionic acid (XVII).



This was the only really doubtful reaction in the series postulated. Methylenepyruvic acid is an entirely reasonable product of plant metabolism, and after the addition of the sulfur in whatever form, there results an α-keto acid such as, according to Knoop, should be readily converted to a methionine derivative by standard biological routines.

The addition products (XV) of benzalpyruvic acid have been made with benzyl and p-tolyl mercaptans, and with thioacetic acid, and identified as their oximes (XVI). Addition of hydrogen sulfide also occurs readily, but no serious attempts have yet been made to isolate the product.

You are asked to consider the hypothetical methionine synthesis thus briefly presented, not as a phantasy that begins and ends nowhere, but as a definite and coherent outgrowth of the more definite results already reported for cystine. It is at least possible that plants actually do make methionine in some such way.

I now wish to change the subject again, and return to cystine. There remain to be discussed the questions as to why cystine is not freely synthesized by animals, and how it may be so synthesized.

Clearly, if we accept the picture offered a few minutes ago, it becomes necessary to assume that the whole organic skeleton from which cystine is produced, exists regularly, and quite as a matter of routine, in animals as well as in plants. In plants, a ready synthesis of cystine results. In animals, the synthesis takes place, *if at all*, to a very insufficient extent, unless there is fed either methionine or homocystine. And yet, serine is not an essential amino acid. If the theory is even roughly correct, the difference is simply that the animal body lacks a suitable source of sulfur. The simplest possible source would be sulfide or disulfide ion—the time has not come to discuss whether

cystine or cysteine is first formed. But sulfides are definitely toxic to animals, and the animal body has developed rather efficient mechanisms for preventing their accumulation in any considerable concentration.

Naturally, one cannot feed inorganic sulfides and expect them to arrive at the site of synthesis, and with the animal normal. But there might be some other method by which the necessary sulfur could be supplied.

As already pointed out, we know two substances which are, up to the present, unique in being able to supply cystine deficiencies. We do not actually *know* that methionine and homocystine replace cystine by *causing cystine formation*, but this is certainly much the simplest assumption. The fact that homocystine is as effective as methionine encourages the idea that it is an intermediate in the metabolism of methionine. The further stages in the degradation of homocystine must be somewhat hypothetical. But Knoop's well known oxidative deamination would lead to the α-keto acid. This, according to the principles already discussed in detail, should yield (see, for instance, XII→XI) reversibly hydrogen disulfide and methylenepyruvic acid.

It must be recalled that this oxidative deamination should take place at just the time and place (perhaps the liver) at which the dehydrogenation of the alanyl peptides is going on, to produce the intermediates necessary for cystine formation. And here it is assumed that the cystine formation occurs.

A purely inorganic deficiency would thus have been overcome through the addition of a rather complex organic compound. The thesis at this moment is essentially this: that methionine or homocystine can cause the animal body to produce cystine, but without contributing anything whatever to the organic skeleton of the resulting cystine.

Dr. Brand,[8] who has also interested himself in this problem, has made certain suggestions, some of which he has tested by feeding experiments. None of the tested compounds have as yet produced cystine when fed. The most ingenious of his suggestions, to my mind, is that the intermediate between homocystine and cystine might be a mixed sulfide, $HO_2CCH(NH_2)CH_2CH_2SCH_2CH(NH_2)CO_2H$ (XVIII). This substance has not yet been synthesized for feeding experiments, but I shall ask you to note two things about it. It is possible for it to break down according to a mechanism essentially like that already suggested, to produce cystine; and in that case the

[8] Brand, Block, Kassell, and Cahill, Proc. Soc. Exp. Biol. and Med., 35: 501. 1936.

latter would again have been formed without the contribution of any carbon atoms from the homocysteine portion. Furthermore, the only important change required in the reactions already outlined would be one of order. The sulfur of homocysteine would merely have to become a part of the molecule which was to yield cystine, *before* the degradation of the homocysteine, instead of after it.

Unfortunately, I cannot at present offer you any further evidence as to the course of these reactions. The work has not been completed, and you must share the responsibility for having made me discuss it at this stage. The current plan is to label the homocystine chain by the synthesis of γ-methyl or γ-phenylhomocystine. If one of these, when fed, should show the power to make good cystine deficiencies in a diet, it would be rather clear that its carbon skeleton was not being used for the synthesis.

Dr. du Vigneaud has imagined a mechanism by which three carbon atoms of the chain in homocystine would be retained in the cystine produced. We are in most friendly disagreement, to the extent that I consider his mechanism for this particular reaction as possible rather than probable. He would perhaps make a similar statement about mine.

He is now engaged in a subtler attack on this problem, which involves labeling the homocystine or methionine to be fed, not with methyl or phenyl groups, but with strategically located atoms of deuterium. Neither of us would really ask for anything better than to have the question definitely settled, by whatever process, and with whatever result.

Exactly how this information, when obtained, may be applied to the economic supplementing of deficient diets, is by no means clear. On the other hand, such a possibility exists, and there is also the chance of developing new tools for the study of metabolism.

With the background which I have laid, I should like to shift the field of discussion once more. Dr. Csonka[9] has somewhat recently made a very interesting generalization with regard to the behavior of the various amino acids occurring in proteins, when fed to animals which have been treated with phloridzin. He suggests the rule that those amino acids which are freely produced by animals, cause sugar formation under these conditions. On the other hand, "essential" amino acids, which animals are apparently unable to synthesize, or to synthesize in adequate amount, should not cause sugar formation.

[9] Csonka (unpublished); presented at Am. Soc. Biol. Chem., Washington, April 1936.

Rather generally, the results of experiment fit the prescribed pattern. But cystine and methionine blur the picture somewhat. Both produce sugar. Now methionine is rather definitely, by present data, essential. Cystine I have already spoken of as "nearly essential," for reasons I have given, though Dr. Csonka prefers to call it non-essential, for reasons with which I cannot very fully agree.

The logic behind this generalization of Dr. Csonka's is, it seems to me, this. If a given amino acid, in the course of its biological breakdown, produces any essential substance in the chain of reactions by which the body normally breaks down and builds up sugars, it will, in phloridzinized animals, cause sugar production.

If one assumes, not unreasonably (although the logical necessity is not entirely complete), that most or all of these reactions are biologically reversible, then the odds are very good that, if a given amino acid produces sugar under these circumstances, the normal metabolism of sugar will produce also the organic intermediates required to allow the body to produce the amino acid in question. Stated thus, the principle has a simple basis, and we should expect it to be moderately general, as indeed it appears to be.

But there is no reason at all why it should be *completely* general. To my notion, one might well *expect* a limited number of exceptions. These would become, not arguments against the generalization, but simply challenges to explain why the observed variation exists.

Our earlier discussion of mechanisms of formation of cystine and methionine has already made clear a possible explanation of these two exceptions—the sulfur fragment required for synthesis. In the case of methionine there is an additional point involved, but there is not time to discuss it here. I think I should personally have had definite cause to worry, if these two acids, specifically, had *not* been sugar formers.

These exceptions, if we assume them to be thus explained or an occasional additional exception, may perhaps add to the value of Dr. Csonka's rule as much as they detract from it. While the rule will have to be used somewhat tentatively in deciding whether a given amino acid is or is not "essential," the exceptions themselves may occasionally help to decide among various mechanisms assumed for the synthesis, by animals, of various amino acids.

If you now have the impression that I have discussed the problems of cystine sulfur exhaustingly, you may be right. But if you think I have considered them exhaustively, you are altogether wrong. There is, just for instance, the theory of Schöberl, buttressed by a certain

number of facts, and based almost entirely on "model" experiments. I shall later have arguments about that with some of you—but not tonight.

Of those of you who have followed me thus far, I am sure that many will agree with me that biochemistry by analogy may be a most dangerous adventure. Certainly, any conclusions reached by such a process should be most carefully controlled by more direct experiments, as soon as these become possible.

But I can at least hope to have some of you agree that processes of the type outlined possess a considerable fascination, which is perhaps not merely that of their danger, and that they may at the very least be profitable for their power to suggest theories which must later be tested more rigorously.

PALEONTOLOGY.—*Oligocene faunas from the lower and upper beds on the A. L. Parrish farm, Washington County, Florida.*[1] W. C. MANSFIELD, U. S. Geological Survey.

The locality from which the fossil material, on which this paper is based, was obtained is in a small ravine, the stream in which disappears in the bottom of a sink, back of the house on the A. L. Parrish farm, about 3½ miles southeast of Wausau, Washington County, Florida. The first reference to this locality is given by Mossom (1). He reports twenty feet of cream-white soft limestone in a sink at this locality. He states that the contained fossils indicate, based on a letter of Miss Julia Gardner, that it is older than the Chipola marl and probably belongs to the Tampa. An analysis of the limestone as reported by Mossom, which probably is from the lower part of the exposure, showed a percentage of 94.7 of calcium carbonate. The limestones were not differentiated.

The second reference is by Cooke and Mossom (2). They state that the lower part of the limestone is white, finely granular, apparently pure, and contains few fossils; the upper part is more argillaceous and carries an abundant fauna, which appears to be of Tampa age.

The third reference is by Dr. T. W. Vaughan (3a). Doctor Vaughan states:

"The third collection, sink on A. L. Parrish farm, 3½ miles southeast of Wausau, Washington County, Florida, contains poorly-preserved specimens, but I think a definite opinion as to the geologic age is justified. One specimen undoubtedly represents the same species as Cushman's *L. chattahoocheensis*

[1] Received January 24, 1938.

and another is clearly the one which I have been calling *L. gigas* var. Other specimens seem to represent the same species as the smaller, thin, flattish or saddle-shaped megalospheric specimens found near Duncan Church. Therefore, I have no hesitancy in expressing the opinion that this material is also Glendon, middle Oligocene age."

It is not stated from which bed the foraminifera were collected, but evidently they came from the lower bed.

The fourth reference is by Mansfield (4). In referring to this locality Mansfield writes:

"The limestone is separable into two beds, the lower of which is believed to be of the same age as that of the limestone exposed at Duncan Church." In reference to the fauna of the upper bed the writer states "this fauna has not been studied sufficiently to determine definitely its relation to the Tampa fauna."

The first lot of fossils collected from the A. L. Parrish farm was obtained by F. G. Clapp in 1920 (U.S.G.S. No. 8854–5–6). Although his station numbers record different levels in a "40-foot outcrop," all the fossils appear to have been taken from the upper fossiliferous bed; the second lot by Dr. C. W. Cooke and Dr. Julia A. Gardner in 1921 (U.S.G.S. No. 10461); and a third lot by the author and G. M. Ponton, 1932, and F. Stearns MacNeil, 1936, and C. W. Mumm, 1937 (U.S.G.S. No. 12723).

An examination by the writer of the section at this place revealed the existence of two beds. The lower bed consists of a soft, nearly white limestone composed almost entirely of large foraminifera but without any observed mollusks. About 8 feet of this bed is exposed in the lowest part of the sink at the place where a small stream disappears. The upper or overlying bed, which may be as much as 25 feet thick here, consists of a limestone containing many mollusks preserved as molds. As there has been much slumping of the strata surrounding the sink, it is difficult to determine with exactness the original position of the upper fossiliferous bed, but it appears to be near the top of the section here. No unconformity was observed between the two beds, the separation being based on the differences in the lithologies and the faunas.

The photographs used for illustrations were made by Nelson W. Shupe, and the prints were retouched by Frances Wieser, both of the U. S. Geological Survey.

Comparison of species from the A. L. Parrish farm with species in outside formations:

MOLLUSKS (upper bed)

SPECIES FROM A. L. PARRISH FARM	SPECIES IN OUTSIDE FORMATIONS
Terebra sp.	Not determined
Conus, ? aff. *C. cookei* Dall	*Conus cookei*, Flint River formation, upper Oligocene
Conus aff. *C. imitator* Brown and Pilsbry	*Conus imitator* Brown and Pilsbry, Baitoa formation, Dominican Republic, and Gatun formation, Canal Zone.
"Drillia" sp.	Not determined.
**Olivella* aff. *O. mississippiensis* Conrad	*O. mississippiensis*, Oligocene
**Mitra* sp.	Cf. undescribed species from the Flint River formation, upper Oligocene.
**Phos parrishi*, n. sp.	Not determined
**Cassis* sp.	Probably near an undescribed form from the Flint River formation.
Ficus aff. *F. mississippiensis* Conrad	*F. mississippiensis*, Oligocene
Strombus aff. *S. liocyclus* Dall.	*S. liocyclus*, Tampa limestone
**Clava parrishi*, n. sp.	Not found elsewhere
†*Turritella gatunensis* Conrad	Vamos-a-Vamos bed and lower bed of Gatun formation; also Chickasawhay
Xenophora sp.	Not determined
Ampullina? sp.	Not determined
**Anadara macneili*, n. sp.	*A. dodona* Dall, Oak Grove sand
**Anadara mummi*, n. sp.	*A. santarosana* Dall, Oak Grove sand; Chickasawhay
Thracia?	Not determined
Crassatellites sp.	Not determined
Venericardia sp.	Not determined
Phacoides (*Miltha*) cf. *chipolana* Dall	*P. chipolana*, Chipola formation and Oak Grove sand
Divaricella sp.	May be the same as undetermined species from upper bed at Falling Water
†*Cardium* aff. *C. hernandoense* Mansfield	*C. hernandoense*. Suwannee limestone; also probably Chickasawhay
**Chione* cf. *C. spenceri* Cooke	Tampa limestone at Cherokee sink and upper bed at Falling Water
Semele aff. *S. smithii* Dall	*Semele smithii*, Chipola formation
Psamosolen aff. *P. sancti-dominica* Maury	*P. sancti-dominica*. Bowden marl. Jamaica; Cercada and Gurabo formation, Dominican Republic
Spisula? sp.	Not determined
Panope cf. *P. parawhitfieldi* Gardner	*P. parawhitfieldi*, Oak Grove sand, Florida

* Rather abundant. † Very abundant.

SPECIES FROM A. L. PARRISH FARM	SPECIES IN OUTSIDE FORMATIONS
Teredo? *incrassata* Gabb	Suwannee limestone, Oligocene; Chickasawhay; Cercado formation, Dominican Republic, Miocene

The following notes on the Foraminifera from the upper and lower beds are by Lloyd G. Henbest of the U. S. Geological Survey:

Two collections of limestone from an outcrop in a sink on the A. L. Parrish farm, 3½ miles southeast of Wausau, Washington County, Fla., were recently submitted to me by W. C. Mansfield for age determination. These two collections represent two horizons. The lower one (U.S.G.S. 13857) is a very soft, porous, friable limestone containing an abundance of Orbitoididae and nullipores. The collection from the upper horizon (U.S.G.S. 12723) consisted of about 25 small pieces of well-indurated matrix that originally surrounded shells of Mollusca.

Lower bed.—Collection 13857, from the lower bed, contains *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* Cushman, *L.* (*Eulepidina*) *undosa* Cushman, *L.* (*Eulepidina*) *favosa*? Cushman. The search has not been exhaustive, and other species may be present.

This fauna is identical with that described by W. Storrs Cole (3). On p. 21 Cole states that a collection from a sink on the A. L. Parrish farm, 3½ miles southeast of Wausau (same locality as 13857) was also a subject of study and definitely implies that it contains the same orbitoidal fauna as that from the Duncan Church locality. Although Cole does not state whether his collection was derived from the upper or lower parts of the section, the detailed similarity of the orbitoidal fauna in our collections from the same locality indicates that his collection also came from the lower bed.

Cole, quoting opinions by Vaughan (3, pp. 21, 22) concludes that the Duncan Church orbitoidal fauna definitely represents Oligocene age and strongly indicates the middle Oligocene. From my own brief study of this collection I find no evidence for contradicting or materially adding to that already presented by Cole; accordingly, there is no need to review his argument here.

Upper bed.—I find in this material (collection 12723) numerous scraps of echinoderm plates and a few small nullipore colonies. Miliolids (including *Quinqueloculina*, etc.), *Amphistegina*?, *Archaias*??, and a few other forms recognizable only as foraminifers were intersected by the sections. In these exposures their specific and in some instances

even their generic identity is not definitely determinable. A peculiar, uniserial peneroplid was encountered whose generic position is uncertain and may represent a new genus. The foregoing list of forms merely suggests Cenozoic age and nothing closer. Of more significance, however, are a few more or less worn fragments of a minute species of *Lepidocyclina*. Fewer unworn or incompletely exposed but subgenerically unidentifiable specimens were found. Two isolated proloculi of *Lepidocyclina* (*Nephrolepedina*) and two specimens of a minute species very closely related to *Lepidocyclina* (*Lepidocyclina*) *yurnagunensis* were found. The two specimens of *L.* (*L.*) *yurnagunensis* differ from those described by Cole from the Duncan Church locality by being more nephrolepidine. Their slightly smaller size may be accounted for as merely individual variation. Another poorly preserved specimen in equatorial section resembles *L. supera*, but a definite identification cannot be made without better sections.

If these lepidocyclines from the upper bed are indigenous and *not erratics derived from the lower bed*, the age is also Oligocene. A closer age determination should not be attempted at the present time on this fragmentary evidence. The other Foraminifera cannot be regarded as supporting or contradicting this evidence, because in their unrecognizable condition they merely indicate Cenozoic age and nothing more exact.

It is probably significant in this connection that though various genera of Foraminifera, including a peneroplid, are present, the faunule does not include any of the highly specialized Peneroplidae that characterize the Tampa and Chipola Miocene in the same general region.

FAUNAS OF THE LOWER AND UPPER BEDS

Lower bed.—So far only specimens of Foraminifera have been collected from the lower bed. Relying on the determinations of these Foraminifera by Cole, Vaughan and Henbest, the age evidently is middle Oligocene.

Upper bed.—Although the sculpture of the external molds of the mollusks has been well preserved, impressions taken of these molds reveal in most cases only parts of the original shell and for that reason the relationships to better preserved specimens from outside localities are difficult to determine.

The molluscan fauna is interesting because a number of forms show a relationship either to the lower part of the Gatun formation or to the Vamos-a-Vamos beds of the Canal Zone and to certain

faunas of the West Indies, thereby probably indicating a migration of the faunas either northward or southward, during this or a closely related geological epoch.

The age of the fauna is believed to be not later in time than that of the Tampa limestone, lower Miocene, or earlier than that of the upper part of the Flint River formation (upper Oligocene). However, the evidence, so far deduced, for placing it in the upper Oligocene is stronger than placing it in lower Miocene, Tampa limestone.

The absence of certain genera of mollusks as *Pecten* and others make the correlation with other deposits that contain these genera more difficult. The possibility of procuring some of these lacking genera and better preserved specimens in the future would aid in determining more precisely the age of the bed.

The molluscan forms that indicate an Oligocene age are: *Conus*,? aff. *cookei; Olivella* aff. *mississippiensis; Cassis* sp.; *Anadara macneili* (an intermediate form between *A. lesueuri* (Dall), an Oligocene species, and *A. dodona* Dall from the Oak Grove sand, but nearer the former); *Cardium hernandoense* Mansfield, Suwannee limestone, upper Oligocene; *Teredo*? *incrassata* Gabb, and perhaps others.

It is the purpose to discuss the Chickasawhay marl of Mississippi and Alabama in this paper only in so far as to indicate the probable relationship of the fauna under discussion with it.

So far as can be observed, the faunas in the upper bed at the A. L. Parrish farm and that of the Chickasawhay are largely contemporaneous. The same *Turritella, Arca, Cardium, Chione* and *Teredo* appear to occur in both.

Two forms that might suggest Tampa age are: *Strombus* aff. *liocyclus* Dall, and *Chione* cf. *spenceri* Cooke.

The nearest locality to the A. L. Parrish farm at which the Tampa limestone fauna occurs is in bed No. 2 at Falling Water, Washington County, a distance of 9 or 10 miles to the north. At Falling Water only one small specimen of a *Chione* similar to that at the A. L. Parrish farm has been collected; this form is rather abundant at the A. L. Parrish farm. *Chlamys crocus* Cooke, a characteristic Tampa limestone species, occurs at Falling Water. The sediments at Falling Water consist mainly of a coarse grained quartz sand, whereas the material of the upper bed at the A. L. Parrish farm consists of a limestone.

Two forms, *Phacoides* cf. *chipolana* Dall and *Panope* cf. *parawhitfieldi* Gardner, suggest a relationship to the Chipola marl or to the Oak Grove sand. The nearest locality to the A. L. Parrish farm

at which Chipola fossils have been collected is in the bed of Econfina River, Bryant Scott's farm, Bay County, sec. 28, T. 2 N., R. 12 W., about 7 miles southeast. This fauna has been placed at the top of the Chipola marl by Dr. Julia A. Gardner (5). This fauna, however, is unlike that at the A. L. Parrish farm.

The fauna of the Baitoa formation, Dominican Republic, contains some forms allied to those at the A. L. Parrish farm. A small cone from the A. L. Parrish farm is similar to *Conus imitator* Brown and Pilsbry (from Baitoa formation) and *Clava parrishi* n. sp. from A. L. Parrish farm is also closely related to an unnamed species from the Baitoa formation.

The *Turritella*, which I have identified as *T. gatunensis* Conrad, is the most abundant species at the A. L. Parrish farm. *T. gatunensis* occurs both in the Vamos-a-Vamos beds (dark-colored beds) and the lower part of the Gatun formation of the Panama Canal zone. Woodring (6) places the Vamos-a-Vamos beds in the lower part of the middle Miocene. The Vamos-a-Vamos beds probably are stratigraphically lower than middle Miocene.

Concerning the fragmental and poorly preserved specimens of foraminifera from the upper bed as determined by L. G. Henbest in this paper, he states "if the *lepidocyclines* found in this bed are indigenous *and not erratics derived from the lower bed*, the age is Oligocene."

A tentative conclusion deduced from a study of the faunas of the upper bed, would indicate that it is Oligocene, and the bed enclosing the faunas is contemporaneous, in part at least, with the Chickasawhay marl of Mississippi and Alabama, the Flint River formation of Georgia, the Suwannee limestone of Florida and the Vamos-a-Vamos beds of the Canal Zone.

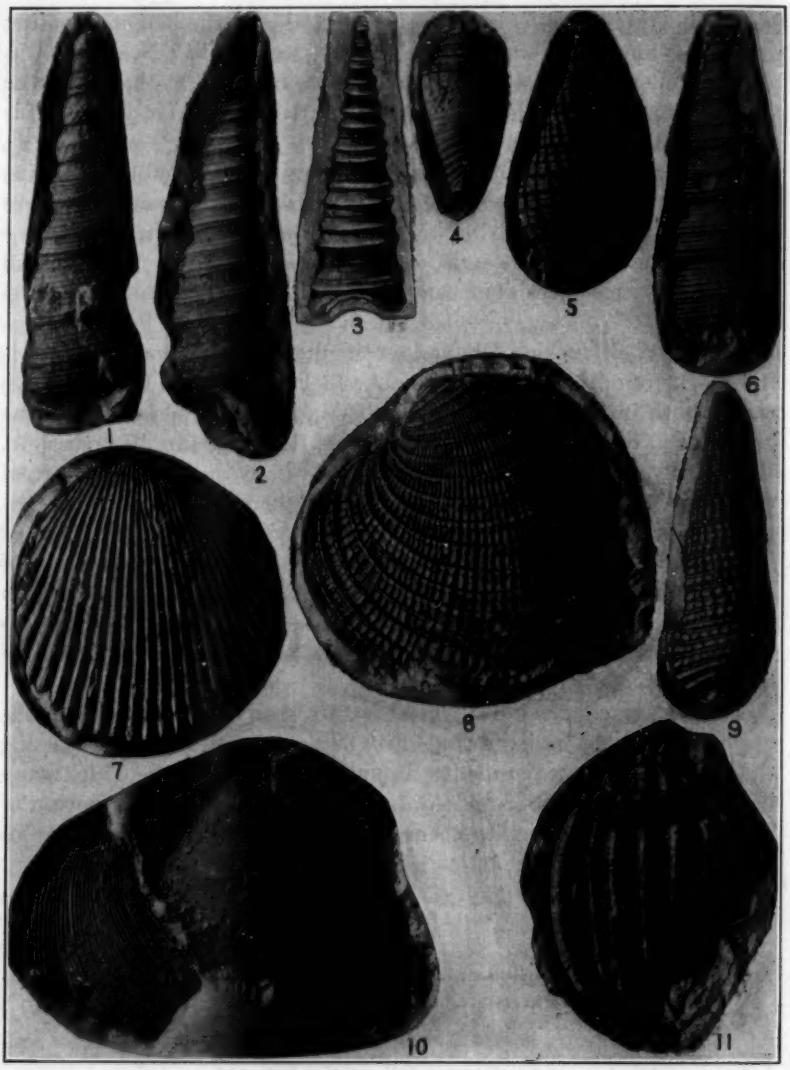
SPECIES OF MOLLUSKS FROM THE UPPER BED

Terebra sp.

One external mold; species not determined.
Occurrence: A. L. Parrish farm.

Conus sp.? aff. *C. cookei* Dall

One rather large external mold showing part of last whorl. The sculpture consists of rather wide spiral bands separated by narrow impressed lines. The nature of the sculpture suggests a relationship to *Conus cookei* Dall from the Flint River formation (upper Oligocene) of Georgia but this relationship cannot be fully confirmed with the material at hand.
Occurrence: A. L. Parrish farm.



Figs. 1, 2, 3, 6.—*Turritella gatunensis* Conrad. Squeezes: 1, ×4; 2, ×3; 3, ×5; 6, ×2. U. S. Nat. Mus. No. 497647. Fig. 4.—*Conus* aff. *C. imitator* Brown and Pilsbry. Squeeze, ×3. U. S. Nat. Mus. No. 497643. Fig. 5.—*Phos parrishi* Mansfield. Squeeze of holotype, ×3. Fig. 7.—*Cardium* (*Trachycardium*) aff. *C. hernandoense* Mansfield. Squeeze, ×2. U. S. Nat. Mus. No. 497653. Fig. 8.—*Chione* cf. *C. spenceri* Cooke. Squeeze, ×3. U. S. Nat. Mus. No. 497654. Fig. 9.—*Clava parrishi* Mansfield. Squeeze of holotype, ×2. Fig. 10.—*Phacoides* (*Milkha*) cf. *P. chipolana* Dall. Squeeze, ×3. U. S. Nat. Mus. No. 497652. Fig. 11.—*Cassis* sp. Squeeze, ×2. U. S. Nat. Mus. No. 497645. (smaller specimen). All enlargements approximate.

Conus aff. *C. imitator* Brown and Pilsbry Fig. 4

Two external molds of small specimens. These specimens have a rather high spire. The whorls are carinate. These specimens closely resemble *Conus imitator* Brown and Pilsbry, a species from the Baitoa formation, Dominican Republic. *C. imitator* also occurs in the Gatun formation of the Canal Zone.

Occurrence: A. L. Parrish farm.

"Drillia" sp.

One incomplete external mold, species not determined.

Occurrence: A. L. Parrish farm.

Olivella aff. *O. mississippiensis* Conrad

External molds of a rather large species. These may be related to *Olivella mississippiensis* Conrad, a Vicksburg, Oligocene species.

Occurrence: A. L. Parrish farm.

Mitra sp.

External molds of large shells of *Mitra*. The sculpture of the undetermined species consists of rather widely spaced alternating stronger and weaker spirals over the whole shell. It appears to be closely related to an undescribed species from the Flint River formation of Georgia.

Occurrence: A. L. Parrish farm.

Phos parrishi Mansfield, n. sp. Fig. 5

Shell of moderate size with an acute spire and rather large body whorl, both spirally and axially sculptured, the axials being more strongly developed on the spire than on last whorl. Sculpture of penultimate whorl consists of 4 primary spirals interposed by a single secondary thread. Two secondary threads lie below the suture. Axials stronger than spirals and are weakly nodulated by the overrunning primary spirals.

Holotype (U.S.Nat.Mus. No. 497644) measures: Length about 15 mm; diameter, about 8 mm.

Type locality: A. L. Parrish farm, Washington County, Florida.

Cassis sp. Fig. 11

Internal molds of rather large shells and incomplete external molds of smaller shells are in hand. These larger and smaller specimens, however, may not represent the same species. The smaller external molds have rather strong axials on the body whorl and in this respect indicate some relationship to *Cassis sulcifera* Sowerby but the ribs are stronger than on this species and the spire is higher. The undetermined specimens probably are more closely related to a rather high-spired form in the Flint River formation of Georgia wrongly identified by Dall as *C. sulcifera*, but the material in hand does not warrant at present uniting the two forms under the same species.

Occurrence: A. L. Parrish farm.

Ficus sp. aff. *F. mississippiensis* Conrad

Incomplete external and internal molds showing a medium sized form of the original shell. With the material in hand it is difficult to determine whether the unidentified form is closer to *Ficus mississippiensis* Conrad,

a Vicksburg, Oligocene species, or to a larger form from the Chipola marl. The secondary spirals appear to be closer to the Chipola species. However, it may be more closely related to the Vicksburg species. It is larger than most of the specimens from the Oligocene and nearly as large as the Chipola specimens.

Occurrence: A. L. Parrish farm.

Strombus aff. *S. liocyclus* Dall

The material consists of incomplete external molds. The body whorl is without tubercles. Sculpture on the spire consists of broad ribs and spirals situated below the suture. The unnamed species appears to be closely related to *Strombus liocyclus* Dall from the Tampa limestone although it may not be that species.

Occurrence: A. L. Parrish farm.

Clava parrishi Mansfield, n. sp. Fig. 9

Shell of medium size, slender; nucleus not preserved. Whorls nearly straight in outline and shallowly constricted by a distinct suture. Sculpture consists of both spirals and axials—the axials being a little weaker than the spirals. The spiral sculpture on the spire whorls consists of three narrow, equally spaced, uniformly sized, nodulous bands and a single intervening thread. A spiral thread, a little stronger than intervening ones, lies adjacent to and behind the suture. Last whorl with 6 nodulous primary spirals, all intercalated with a single secondary thread except the basal two, which have two secondary threads instead of one. Axials, probably about 15 in number, arcuate, weaker than spirals and extend across each whorl.

Holotype (U.S.Nat.Mus. No. 497646) measures about 26 mm (including broken off tip which probably amounts to about 3 mm); diameter, about 8 mm.

Type locality: A. L. Parrish farm, about 3½ miles southeast of Wausau, Washington County, Fla.

Clava parrishi n. sp. is closely related to an unnamed species from the Baitoa formation, lower Miocene, from the Province of Santiago, Dominican Republic, stations 8668 and 8558. The upper spiral on the Baitoa species is a little stronger than the others whereas this spiral on the new species here described is no stronger than the others.

"Cerithium" praecursor Dall, a species in the Tampa limestone, has a stouter shell and more secondary spirals than the new species here described.

Occurrence: Type locality, quite common. Not found elsewhere.

Turritella gatunensis Conrad Figs. 1–3, 6

Specimens of *Turritella* are very abundant at the A. L. Parrish farm. The depression between the two raised spirals on each whorl on these specimens begins on the early part of the shell and continues over the later whorls. The depression on the early whorls appear to characterize the earliest forms referred to *Turritella gatunensis* from later forms which have a medial carina on the 7 or more earliest whorls which is formed by the upper spiral —the lower spiral, which is developed later, gradually strengthens anteriorly.

In examining specimens referred to *T. gatunensis* from G formations of the Canal Zone two varieties are observed. In one variety, which occurs in the Vamos-a-Vamos bed and in lower faunal zone of the Gatun forma-

tion, a depression develops on the early whorls whereas in the second variety occurring in the middle faunal zone of the Gatun formation at the Gatun dam (Station 8365 and other stations) the earliest whorls are medially carinated, the anterior spiral coming in later.

The form at the A. L. Parrish farm more closely resembles those from the Vamos-a-Vamos and in lower faunal zone of the Gatun formation.

The Culebra formation of the Panama Canal Zone contains a different species of *Turritella*.

Turritella gatunensis caronensis Mansfield from the Brasso beds of Trinidad perhaps is more closely related to those in the middle faunal zone of the Gatun formation.

Turritella gatunensis blountensis Mansfield from the upper middle Miocene of Florida have weakly carinated early whorls, a shallower suture and lower primary spirals than those in the Gatun formation.

Two external molds showing the early parts of a *Turritella* have been collected at Station 13396, above the mouth of Limestone Creek, near the middle of sec. 25, T. 9 N., R. 7 W., Wayne County, Mississippi, by Roy T. Hazzard. These probably belong to *Turritella gatunensis* Conrad. Specimens from Station 1/52, Gainstown Ferry, Clarke County, Alabama, referred by Cooke (7) to the Chickasawhay marl member of the Byram marl, are the same as those at the A. L. Parrish farm.

Xenophora sp.

External mold of base, species not determined.
Occurrence: A. L. Parrish farm.

Ampullina? sp.

Internal molds, genus not determined.
Occurrence: A. L. Parrish farm.

Anadara macneili Mansfield, n. sp. Figs. 12, 17, 18

Shell small, ovate, moderately high, inequilateral, and probably nearly equivalve. Beaks weakly depressed medially. Left valve narrowly rounded over anterior side, weakly truncate on posterior side and broadly rounded over the middle. Ribs over beak and early part of the shell single and beaded and separated by interspaces about as wide as the ribs. The ribs begin to divide at about the highest part of the shell forming two closely spaced ribs, the sulcation becoming deeper in advancing ventrally. Near the posterior border each bi-partate rib is shallowly sulcated forming four radials. Right valve, so inferred, has similar ribs as left.

Holotype, left valve (U.S. Nat. Mus. No. 497648) measures length about 25 mm; width about 20 mm; height about 8 mm.

The paratype (Fig. 17) shows only the anterior half of the shell. The species is described from squeezes taken from exterior molds.

Type locality: A. L. Parrish farm, 3½ miles southeast of Wausau, Washington County, Fla.

Compared with *A. lesueuri* (Dall), a Vicksburg species, the new species is larger, relatively higher and wider, with a more medially impressed beak.

The general outline of the shell of the new species, and the character of its ribbing agree closely with that of *A. dodona* Dall, an Oak Grove species. It appears, however, to be an intermediate form between the Vicksburg species and the later species.

The species is named after F. Stearns MacNeil of the U. S. Geol. Survey.

Anadara mummi Mansfield, n. sp. Fig. 14

Shell rather small and moderately high with a truncate posterior side. Ribs slightly wider than interspaces, strongly beaded, single over the umbo but divided over the lower half of the shell. The shell is relatively higher and stouter, more truncate on the posterior side than *Anadara macneili*, and the ribs show no indication of breaking up into four parts.

Holotype, left valve (U. S. Nat. Mus. No. 497651) measures: Length, about 20 mm; width, about 20 mm; height, about 9 mm.

Type locality: A. L. Parrish farm, 3½ miles southeast of Wausau, Washington County, Florida.

The new species appears to be related to *A. santarosana* Dall, an Oak Grove species, apparently differing from the latter in having a smaller shell, with the incisions on the ribs earlier developed.

Compared with *Anadara hypomela silicata* Mansfield, a Tampa limestone subspecies, the new species has a shorter shell, a more truncate posterior side and more beaded ribs.

Other occurrence: Specimens collected at Station 13239, NW¼ sec. 17, R. 8 N., T. 5 W., Bucatunna Creek, Wayne County, Mississippi, appear to belong to the same species.

The species is named after C. W. Mumm of the U. S. Geol. Survey.

Thracia? sp.

Fragment showing internal mold. The ribbing suggests that it may belong to the genus *Thracia*.

Occurrence: A. L. Parrish farm, Washington County, Florida.

Crassatellites sp.

One internal mold, species not determined.

Occurrence: A. L. Parrish farm, Washington County, Florida.

Venericardia sp.

External molds of incomplete shells. Species not determined.

Occurrence: A. L. Parrish farm, Washington County, Florida.

Phacoides (*Miltha*) cf. *P. chipolana* Dall Fig. 10

External mold of an incomplete left valve. The fine concentric sculpture indicates that it is either very close to or the same as *Phacoides* (*Miltha*) *chipolana* Dall, a species occurring in the Chipola marl and the Oak Grove sand.

Occurrence: A. L. Parrish farm, Washington County, Florida.

Divaricella sp.

External mold of an incomplete shell. Species not determined. This may be the same undetermined species as occurs in the upper bed at Falling Water.

Occurrence: A. L. Parrish farm, Washington County, Florida.

Cardium (*Trachycardium*) aff. *C. hernandoense* Mansfield Figs. 7, 13

External and internal molds of several specimens, which probably represent a single species. The ribs are rather closely spaced, triangular in outline and without any observed granules. The specimens have more ribs than

Cardium precursor Dall, a species from the Oligocene at Vicksburg, Miss., but show some affinity to it.

Cardium (*Trachycardium*) *hernandoense* Mansfield from the Suwannee limestone, upper Oligocene, appears to be closely related to it.

Occurrence: A. L. Parrish farm, Washington County, Florida.

Other occurrence: External impressions from Station 13396, Hillside above the mouth of Limestone Creek, Wayne County, Miss. (sec. 25, T. 9 N., R. 7 W.) may be closely related to the unnamed species.

Chione cf. *C. spenceri* Cooke Figs. 8, 16

Material consists mainly of a number of external molds. These external molds compare closely with *Chione spenceri* Cooke from Antigua but specific identity with that species is not confirmed.

The molds show a moderately large shell, inflated, about as long as wide, and weakly depressed behind the middle. Sculpture consists of erect, concentric lamellae and rather strong radials. These lamellae are about 2 millimeters apart over the whole shell. These radials undulate the margins of the lamellae and ornament their ventral slopes and extend across the rather wide interspaces.

Occurrence: A. L. Parrish farm, Washington County, Florida.

Other occurrence: Tampa limestone at Cherokee sink, Wakulla County (two small valves); upper bed at Falling Water, Washington County, Fla. (one small valve). Although the specimens from the Tampa limestone are smaller than the specimens from the A. L. Parrish farm, the sculpture on the specimens from the three localities appear to be identical.

The unidentified species differs from *Chione bainbridgensis* Dall, a species occurring in the Flint River formation, upper Oligocene of Georgia, in having (especially over the umbonal area) wider spaced concentric sculpture and stronger radials.

Semele aff. *S. smithii* Dall

The material consists of internal and external molds. The concentric sculpture consists of closely spaced lamellae. The undetermined species appears to be related to *Semele smithii* Dall from the Chipola formation. It has a smaller shell than *Semele chipolana* Dall and the concentric sculpture on it is finer but it may be as closely related to *S. chipolana* as to *S. smithii* Dall.

Occurrence: A. L. Parrish farm, Washington County, Florida.

Psamosolen aff. *P. sancti-dominica* Maury

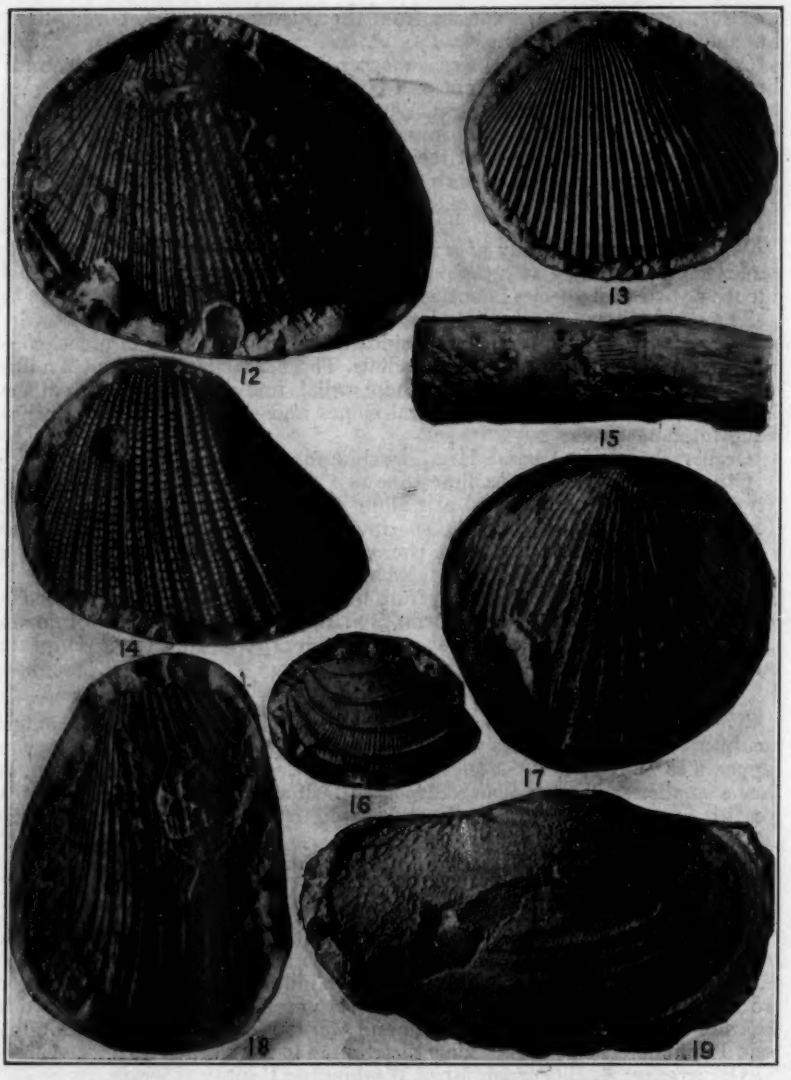
The material consists of an external mold showing about half of the original shell. The exact relationship of this specimen to other species is difficult to determine with the material in hand but it appears to be related to *P. sancti-dominica* Maury, a species reported to occur in the Bowden marl of Jamaica and in the Cercado and Gurabo formations of the Dominican Republic. The genus is widely distributed in the warmer seas.

Occurrence: A. L. Parrish farm, Washington County, Florida.

Spisula? sp.

The material consists of an external mold of part of the original shell. This specimen probably is a *Mactra* or *Spisula*. Not knowing the genus the relationship to other forms cannot at present be determined.

Occurrence: A. L. Parrish farm, Washington County, Florida.



Figs. 12, 17, 18.—*Anadara macneili* Mansfield. 12, squeeze of holotype, ×3; 17, squeeze of paratype, ×3. U. S. Nat. Mus. No. 497650; 18, squeeze of paratype, ×3. U. S. Nat. Mus. No. 497649. Fig. 13.—*Cardium* (*Trachycardium*) aff. *C. hernandoense* Mansfield. Squeeze, ×3. U. S. Nat. Mus. No. 497653. Fig. 14.—*Andara mummi* Mansfield. Squeeze of holotype, ×3. Fig. 15.—*Teredo*? *incrassata* Gabb, ×1. U. S. Nat. Mus. No. 497657. Fig. 16.—*Chione* cf. *C. spenceri* Cooke. Squeeze, ×4. U. S. Nat. Mus. No. 497655. Fig. 19.—*Panope* cf. *P. parawhitfieldi* Gardner, ×2. U. S. Nat. Mus. No. 497656.

Panope cf. *P. parawhitfieldi* Gardner Fig. 19

The material consists of an internal mold of both valves. This specimen measures: Length, about 40 mm; altitude, about 25 mm. The umbo is rather low and is situated about 18 mm from the anterior end. So far as can be determined this specimen most closely resembles *P. parawhitfieldi* Gardner, a species occurring in the Oak Grove sands of Florida; however, an adult specimen of the same species might show differences.

Occurrence: A. L. Parrish farm, Washington County, Florida.

Teredo? *incrassata* Gabb Fig. 15

The material consists of fairly good sized tubes and a few fragments. These tubes occur abundantly in the Suwannee limestone (upper Oligocene) but have not been found in the Tampa limestone (lower Miocene). They occur in the Cercado formation and other horizons in Santo Domingo not definitely placed stratigraphically.

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BOTANY.—*A new species of* Callirhoë.[1] ROBERT F. MARTIN, Bureau of Plant Industry. (Communicated by S. F. BLAKE.)

Nuttalia pedata Nutt. ex Hook. was described in 1827 and transferred by Gray in 1849 when he resurrected the genus *Callirhoë* of Nuttall. Although in later years Gray realized that the original *Nuttallia pedata* was synonymous with *Callirhoë digitata* Nutt., he did not see fit to publish a new name, and *Callirhoë pedata* has continued to be used to designate the common annual poppy mallow of Texas and Oklahoma. That *Nuttallia pedata* is the same plant as *Callirhoë digitata* is shown by the original figure and by a sheet in the Gray Herbarium collected by Hooker in the Glasgow Garden. This sheet is annotated, "An original of *N. pedata.*" Furthermore, according to Carruthers in a letter to Gray, all of Nuttall's specimens of *N. pedata* sent to the British Museum had large perennial roots. It

[1] Received December 29, 1937.

therefore becomes apparent that the annual has never had a valid name and I propose:

Callirhoë leiocarpa Martin, sp. nov.

Callirhoë pedata A. Gray, Mem. Amer. Acad. N. S. **4**: 16 (Pl. Fendl.) 1849, excluding name-bringing synonym; Bost. Jour. Nat. Hist. **6**: 160 (Pl. Lindh.) 1850, p. p.; Pl. Wright. **1**: 15. 1852.

Callirhoë pedata var. *compacta* hort. Damm.; Sprenger, Gartenflora, **35**: 313. 1886.

Not *Nuttallia pedata* Nutt. ex Hook. Exot. Fl. **3**: 172. 1827.

Annua; caules erecti, 30–80 cm alti, glabri et saepe glauci; stipulae ovatae vel ovato-lanceolatae, 5–10 mm longae, lobatae vel auriculatae, ciliatae; folia 3–5-lobata vel incisa, lobis crenatis, supra strigosa; pedunculus 1-florus, glaber vel strigosus; involucellum nullum; sepala lanceolata, acuminata, 10–14 mm longa; petala obcuneata, 15–25 mm longa, 12–18 mm lata, apice erosa, purpureo-rubra, in ungue barbellata; carpella glabra, valde rostrata, in dorso paene laevia.

Annual; stems erect, 30–80 cm high, glabrous and often somewhat glaucous; stipules lance-ovate, 5–10 mm long, lobed or auricled at base, ciliate; petioles of the basal leaves up to 10 cm long, glabrous, strigose, sparingly stellate-pubescent, or rarely pilose, the blades palmately 3–5-lobed or deeply incised, the divisions crenate to coarsely toothed, strigose above, appressed-stellate beneath; stem leaves similar, or usually more deeply incised into narrower divisions, and with shorter petioles; peduncles glabrous, scabrous, or with appressed simple or stellate hairs, one-flowered; involucel wanting; sepals lanceolate, acuminate, 10–14 mm long, glabrous externally, white-hairy along the margin internally, the nerves often white and thickened; petals obcuneate, 15–25 mm long, 12–18 mm wide, erose at apex, purplish-red or cherry, drying bluish, bearded at the base; staminal column hairy; carpels 10–12, about 4 mm high, glabrous, prominently beaked, nearly smooth on the back.—Prairies and hills, chiefly in dry soil, Texas and Oklahoma. April–June.

Type in the herbarium of the National Arboretum, No. 8099, collected by C. D. Marsh, April 4, 1908, near Spofford, Kinney County, Texas.

Specimens Examined (by counties).[1]

TEXAS. Bexar: *Palmer* 33780 (M, NY). Burnet: *Tharp* 1340 (NA, T, US). Coke: *Swift*, 1856 (US). Comal: *Lindheimer* 681 (G, M, NY, P, US). Concho: *Reverchon* (*Curtiss* 362**) (M, NY). Duval: *Croft* 14 (NY). Gillespie: *Jermy* 608 (M, US). Goliad: *Williams* 65 (P, T). Hays: *Stanfield*: Spring 1889 (NY). Howard: *Tracy* 7813 (G, M, NY, T, US). Irion: *Cory* 565 (G, US). Kerr: *Milligan* April (US). Kinney: *Marsh* April 4, 1908 (NA, type). Lampasas: *Wolff* 925 (US). La Salle: *Small & Wherry* 11951 (NY). Live Oak: *Tharp* June 18, 1928 (T). Llano: *Fisher* 90 (F). Lubbock: *Demaree* 7669 (M, US). Nueces: *Hanson* June 7, 1919 (M, NY). San Patricio: *Hanson* 49-a (US). Schleicher: *Jones* May 1, 1931 (T).

[1] The following symbols are used to indicate the herbaria in which specimens are deposited: F, Field Museum of Natural History; G, Gray Herbarium; M, Missouri Botanical Garden; NA, National Arboretum; NY, New York Botanical Garden; P, Academy of Natural Sciences of Philadelphia; T, University of Texas; US, United States National Museum.

Tom Green: *Palmer* 10320 (M). Travis: *Tharp* May 1, 1928 (NA, T). Uvalde: *Palmer* 10182 (M, US). Valverde: *Orcutt* 6046 (M). Victoria: *Tracy* 9235 (G, M, NY, T, US). Wilson: *E. Palmer* August 1879 (G).

OKLAHOMA. Comanche: *Clemens* 11690 (M). Custer: *White* 31 (M). Kiowa: *Stratton* 327 (M). Woods: *Stevens* 1634 (G, M, NY, US).

In general appearance this species often strongly resembles forms of *C. digitata*, from which it may be distinguished by the smoother carpels and slender annual taproot.

ZOOLOGY.—*North American monogenetic trematodes. II. The families Monocotylidae, Microbothriidae, Acanthocotylidae and Udonellidae (Capsaloidea).*[1] EMMETT W. PRICE, U. S. Bureau of Animal Industry.

This paper represents the second of a series on the North American monogenetic trematodes and deals with the superfamily Capsaloidea exclusive of the Capsalidae. The organization and purpose of this paper are the same as for the first of the series (Price, 1937). With few exceptions, the species considered in this installment are those previously described by the late Dr. G. A. MacCallum.

Superfamily CAPSALOIDEA Price, 1936

Diagnosis.—Anterior haptors present or absent; when present in form of a weakly developed oral sucker or pseudosucker, or of 2 laterally placed suckers, or of corresponding glandular grooves; head organs sometimes present. Posterior haptor disc-like, usually relatively large and muscular, ventral surface frequently divided by septa into sucker-like depressions, with or without hooks; hooks, when present, never with cuticular supporting bars. Intestine single or consisting of 2 branches frequently provided with median and lateral dendritic diverticula. Genital aperture median or lateral. Cirrus sometimes cuticular, without cuticular accessory structures except in *Anoplodiscus* (Microbothriidae). One or more testes. Vagina present or absent. Oviparous.

Type family.—Capsalidae Baird, 1853.

KEY TO FAMILIES CAPSALOIDEA

1. Anterior haptors in form of a pair of suckers or corresponding glandular depressions 2
   Anterior haptors not in form of a pair of suckers or corresponding glandular depressions 4
2. Intestine single ..... UDONELLIDAE Taschenberg
   Intestine double 3
3. Male and female genital apertures close together .. CAPSALIDAE Johnston
   Male and female genital apertures not close together ..... ACANTHOCOTYLIDAE Price
4. Posterior haptor provided with hooks .... MONOCOTYLIDAE Taschenberg
   Posterior haptor not provided with hooks ..... MICROBOTHRIIDAE Price

[1] Received January 7, 1938.

Family MONOCOTYLIDAE Taschenberg, 1879

Diagnosis.—Body elliptical or oval, flattened dorsoventrally. Anterior haptor present or absent; when present, in form of an oral sucker or several preoral suckers; cephalic glands present. Posterior haptor disc-like, with ventral surface usually divided by septa into depressed sucker-like areas, and armed with 1 pair of large hooks (absent in *Empruthotrema*) and 14 marginal hooklets. Oral aperture ventral, near anterior end of body; pharynx relatively large; esophagus very short or absent; intestinal branches without diverticula, sometimes united posteriorly. Eyes present or absent. Genital aperture usually median; cirrus heavily cuticularized, except in *Dionchus*. Usually 1 testis, rarely 3 testes or numerous testes. Ovary curved, frequently embracing right intestinal branch. Vagina single or paired, rarely absent.

Type genus.—*Monocotyle* Taschenberg, 1878.

KEY TO SUBFAMILIES OF MONOCOTYLIDAE

1. Posterior haptor without septa ..... LOIMOINAE Price
   Posterior haptor with septa 2
2. Vagina absent ..... DIONCHINAE Johnston and Tiegs
   Vagina present 3
3. Vagina single ..... MONOCOTYLINAE Gamble
   Vagina double 4
4. With oral sucker ..... CALICOTYLINAE Monticelli
   Without oral sucker ..... MERIZOCOTYLINAE Johnston and Tiegs

Subfamily MONOCOTYLINAE Gamble, 1896

Diagnosis.—Anterior haptor in form of a weakly developed oral sucker; posterior haptor with central area bounded by a ridge with 7 or 8 septa radiating from it, and armed with 1 pair of large hooks and 14 marginal hooklets. Eyes present or absent. Vagina probably always present, single.

Type genus.—*Monocotyle* Taschenberg, 1878.

KEY TO GENERA OF MONOCOTYLINAE

1. Ventral surface of haptor with 7 radial septa ..... *Dasybatotrema* Price
   Ventral surface of haptor with 8 radial septa 2
2. Three testes ..... *Tritestis* Price
   One testis 3
3. Oral aperture surrounded by a somewhat membranous pseudosucker ..... *Monocotyle* Taschenberg
   Oral aperture surrounded by poorly developed sucker ..... *Heterocotyle* Scott

Genus MONOCOTYLE Taschenberg, 1878

Diagnosis.—Ventral surface of haptor divided by septa into 8 equal sectors, with 1 pair of large hooks; marginal hooklets (?). Oral aperture almost terminal, surrounded by a somewhat membranous pseudosucker. Eyes absent. One testis. Uterine aperture marginal. Cirrus and vagina (?).

Type species.—*Monocotyle myliobatis* Taschenberg, 1878.

The genus *Monocotyle* contains only the type species, *M. myliobatis*, which was described by Taschenberg (1878) from the gills of *Myliobatis aquila* at Naples; the original description was very brief. Perugia and Parona

(1890) gave a fairly detailed description of a species from *M. aquila* which they regarded as the same as Taschenberg's species, and if their observations are correct, this form differs from all other members of the subfamily in having a laterally placed uterine aperture. The anterior pseudosucker-like haptor appears to resemble closely that of *Dasybatotrema* Price.

Genus HETEROCOTYLE Scott, 1904

Synonyms.—*Monocotyle* Auct.; *Trionchus* MacCallum, 1916; *Monocotyloides* Johnston, 1934.

Diagnosis.—Ventral surface of haptor with central depression surrounded by a ridge from which radiate 8 septa; one pair of large hooks and 14 marginal hooklets present. Oral aperture subterminal, surrounded by poorly developed oral sucker. Eyes present or absent. One testis; cirrus slender, cuticularized. Vagina probably always present.

Types species.—*Heterocotyle pastinacae* Scott, 1904.

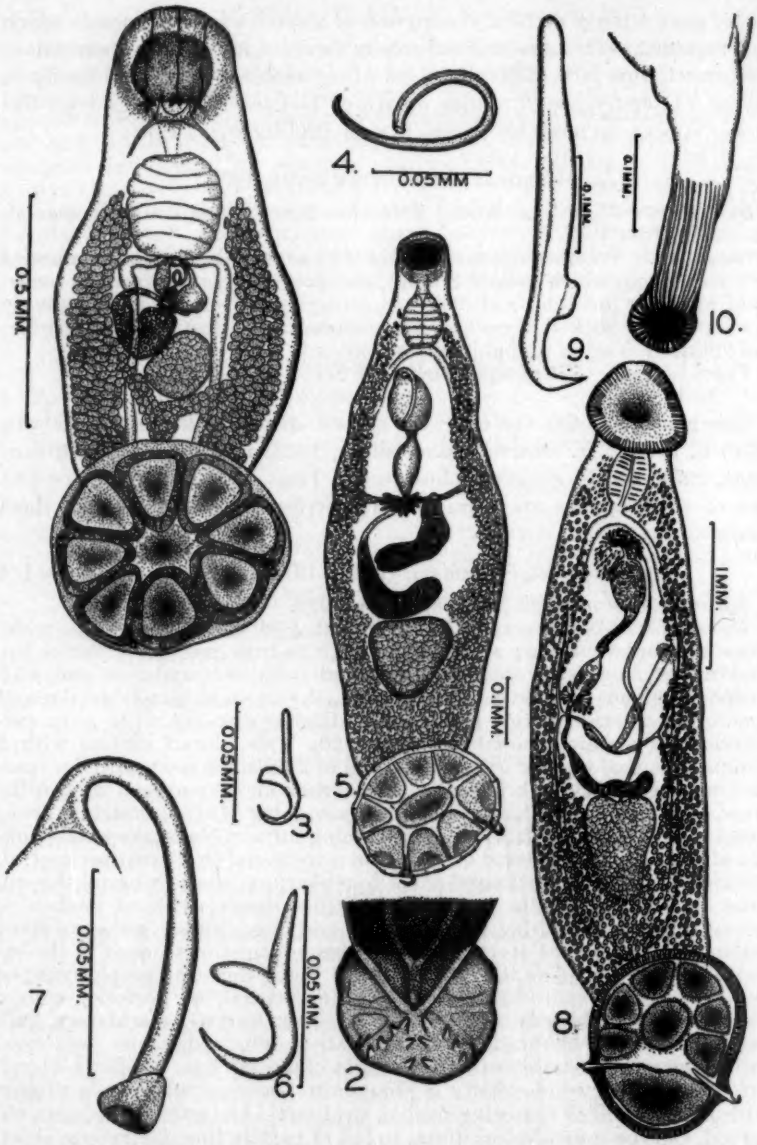
This genus contains the following species: *Heterocotyle floridana* (Pratt, 1910) n. comb.; *H. minima* (MacCallum, 1916) n. comb.; *H. pastinacae* Scott, 1904; and *H. robusta* (Johnston and Tiegs, 1922) n. comb. The first two of these species are from North America and descriptions of them follow.

Heterocotyle floridana (Pratt, 1910), n. comb. Figs. 1–4

Synonym.—*Monocotyle floridana* Pratt, 1910.

Description.—Body more or less elliptical, 1.36 mm long by 500μ wide, flattened dorsoventrally; anterior end with narrow projecting dorsal lip. Oral sucker moderately developed, without definite boundaries, and with 3 cephalic glands imbedded in dorsal wall, the ducts of glands slender and opening at anterior margin of dorsal lip. Haptor disc-like, 480μ wide, surrounded by marginal membrane about 20μ wide; dorsal surface with 2 groups of conical papilla arranged in form of 2 triangles near posterior margin; ventral surface with irregular central area and 8 marginal sucker-like areas, and armed with 2 large hooks and a number (?14) of marginal hooklets. Large hooks about 50μ long, disregarding curve of blade; marginal hooklets about 12μ long, situated on marginal membrane. Oral aperture ventral, 160μ wide, leading into a funnel-shaped prepharynx; pharynx barrel-shaped, 240μ long by 200μ wide; intestinal branches simple, without median or lateral diverticula, uniting near posterior end of body and forming a short common cecum (Pratt stated that this cecum sometimes opens to the exterior through a median, thicklipped pore). Brain dorsal to prepharynx; no eyes. Genital aperture apparently median, ventral, at posterior end of pharynx. Cirrus heavily cuticularized, slender, curved; ejaculatory bulb curved, to right of cirrus. Testis median, about 160μ in diameter, postequatorial. Ovary curved, pretesticular, to right of median line. Vitellaria lateral, extending from level of equator of pharynx to posterior end of body proper, with band of follicles crossing median field distal to testes. No vagina observed. Ootype somewhat piriform, to left of median line; metraterm short, apparently opening to exterior through the same pore as cirrus. Egg, according to Pratt, oval and about 45μ long, with short process at one pole.

Host.—*Aëtobatus fréminvillii* (Le Sueur).



Figs. 1–4.—*Heterocotyle floridana*. 1, complete worm, ventral view; 2, haptor, dorsal view, from Pratt, 1910; 3, large haptoral hook; 4, cirrus. Figs. 5–7.—*Heterocotyle minima*. 5, complete worm, ventral view; 6, large haptoral hook; 7, cirrus. Figs. 8–10.—*Dasybatotrema dasybatis*. 8, complete worm, ventral view; 9, large haptoral hook; 10, cirrus.

Location.—Gills.
Distribution.—United States (Gulf of Mexico).
Specimens.—U. S. N. M. Helm. Coll. No. 39582 (cotypes).

Monocotyle floridana was originally described by Pratt (1910) from specimens collected from a whip-ray, taken in the Gulf of Mexico. The above description is based upon a part of the cotype material. According to Pratt, there is no common genital aperture, and no cirrus or penis. While the writer has been unable to determine the presence of a common genital aperture in the material at his disposal, the arrangement of the genital organs is such as to suggest that such an opening is present. On studying the original drawings and description, there appears to have been some confusion in the interpretation of several structures, the cirrus being mistaken for a vagina, the ejaculatory bulb for a seminal receptacle, and a sharp curve in the vas deferens at the point where it enters the ejaculatory bulb for a vaginal aperture. No vagina was observed in the specimens, but it is possible that fresh material would reveal such a structure. The cephalic glands are shown by Pratt to be 4 in number, but in the specimens at the writer's disposal only 3 could be found; this difference, however, may have no significance, since it is possible that the specimens studied were anomalous with respect to the number of cephalic glands. Pratt also failed to detect the small marginal hooklets occurring in the marginal membrane of the haptor; they are very minute and can be detected only on careful study under the highest powers of the microscope. The exact number of these hooklets could not be determined, but there are probably 14 as in the case of related forms.

H. floridana resembles *H. minima* in size and general appearance, but may be easily differentiated from the latter species by the presence of the 2 groups of conical papillae on the posterior part of the dorsal surface of the haptor, there being no such papillae on the haptor of *H. minima*. Other differences are the presence of eyes and of a conspicuous vagina in *H. minima*, while these structures appear to be absent in *H. floridana;* there is also considerable difference in the cirri of the two species.

Heterocotyle minima (MacCallum, 1916), n. comb. Figs. 5–7

Synonyms.—*Monocotyle dasybatis minimus* MacCallum, 1916; *Monocotyle minima* (MacCallum, 1916) Johnston and Tiegs, 1922; *Trionchus dasybatis* MacCallum, 1916; *Monocotyloides minima* (MacCallum, 1916) Johnston, 1934.

Description.—Body elliptical, flattened dorsoventrally, 945μ to 1.02 mm long by 270 to 340μ wide, anterior end with narrow projecting lip. Oral sucker 76 to 85μ wide; haptor disc-like, 247 to 278μ wide, surrounded by marginal membrane about 25μ wide; ventral surface with oval central area and 8 marginal areas separated by septa, armed with 2 large hooks, 1 hook inserted in each of the postero-lateral septa, and 14 marginal hooklets imbedded in the marginal membrane. Large hooks 53 to 57μ long, disregarding curvature of blade; marginal hooklets about 10μ long. Nature of nervous systerm not ascertainable; remnants of eyes present on each side of pharynx.

Oral aperture ventral, subterminal, about 38μ in diameter. Pharynx barrel-shaped, 95μ long by 68μ wide, marked with 6 or 7 transverse grooves; esophagus very short or absent; intestinal branches simple, extending to near posterior end of body proper, their tips approaching but not fusing. Common genital aperture median, 290 to 340μ from anterior end of body. Cirrus cuticularized, expanded and strongly curved proximally, truncate distally. Ejaculatory bulb oval, 95μ long by 57 to 76μ wide. Testis single, subtriangular with base directed anteriad, about 133μ long by 114μ wide, median, in posterior third of body. Ovary elongate, curved, pretesticular. Vitellaria lateral, extending from level of equator of pharynx to posterior end of body proper, uniting in median field distal to testis. Vagina relatively large, curved, lying largely in median field, opening slightly to left of median line at level of transverse vitelline duct. Mehlis' gland consisting of a number of large cells with relatively long, slender ducts, median, at junction of oviduct and vitelline duct. Ootype oval, relatively large, median. Egg triangular, about 95μ wide, with relatively long, slender filament.

Hosts.—*Dasyatis pastinaca* (Linnaeus), *Squalus acanthias* Linnaeus, and *Pastinachus centrourus* (Mitchill).

Location.—Gills.

Distribution.—United States (Woods Hole, Mass.)

Specimens.—U. S. N. M. Helm. Coll. Nos. 35649 (cotypes), 35650 (type of *Trionchus dasybatis*), 35651, 35652, and 35653.

The above description is based upon about 20 specimens, all toto mounts, representing 4 collections made on different dates by the late Dr. G. A. MacCallum. Most of the specimens were not in good condition because of the technique employed in preserving and mounting them. Sufficient detail, however, could be made out to enable the species to be described with a fair degree of accuracy.

This species is very closely related to *Heterocotyle pastinacae* Scott and may possibly be the same species. Scott's (1904) description and figures of his species were not detailed and it is thought best to regard the two forms as distinct until a restudy of *H. pastinacae* can be made.

MacCallum (1916) described as *Trionchus dasybatis*, nov. gen. et nov. sp., a form from the gills of a sting ray. One specimen (U.S.N.M. No. 35650) of this species was available for examination. A comparison of this specimen with specimens of *H. minima* showed the two forms to be identical, since the middle hook of the haptor, the character upon which the genus *Trionchus* was based, was found to be a fragment of lint which had become attached to the posterior septum in such a manner as to appear like a double pointed hook.

Johnston (1934) placed this species in a new genus, *Monocotyloides*, having *M. robusta* (Johnston and Tiegs) as type. A comparison of *Monocotyloides* with *Heterocotyle* shows that the two genera are synonymous.

Genus Tritestis Price, 1936

Diagnosis.—Ventral surface of haptor divided into equal sectors by 8 radial septa as in *Monocotyle*. Oral aperture ventral, not surrounded by

sucker; anterior end with 4 pairs of gland termini. Eyes present. Three testes.

Type species.—*Tritestis ijimae* (Goto, 1894) n. comb.

This genus contains only the type species which was collected from the mouth of *Trygon pastinaca* (=*Dasyatis pastinaca*) in Japan. This form differs from *Monocotyle* and *Heterocotyle* in the number of testes and in the nature of the anterior end of the body. The anterior end of *T. ijimae* (Goto, 1894) possesses what appear to be head organs ("sticky glands") arranged as a group of 4 on each side of the anterior end of body similar to those in *Empruthotrema* Johnston and Tiegs.

Genus DASYBATOTREMA Price, 1936

Diagnosis.—Ventral surface of haptor divided into 7 sectors by septa, the posterior sector being the largest; one pair of large hooks and 14 marginal hooklets present. Oral aperture slightly subterminal, surrounded by funnel-like pseudosucker having numerous gland termini around margin. Eyes absent. One testis. Cirrus tubular, composed of cuticular bars. Vagina present, opening laterally.

Type species.—*Dasybatotrema dasybatis* (MacCallum, 1916).

Dasybatotrema dasybatis (MacCallum, 1916), n. comb. Figs. 8–10

Synonym.—*Monocotyle dasybatis* MacCallum, 1916.

Description.—Body elliptical, 5 to 7 mm long by 1.2 to 2 mm wide, flattened dorsoventrally. Oral pseudosucker funnel-like, 680 to 935μ wide, with numerous gland openings around margin. Haptor disc-like, 1.2 to 1.8 mm long by 1.1 to 1.6 mm wide, surrounded by a festooned marginal membrane about 75 to 114μ wide; ventral surface divided by ridges into a more or less circular central area and 7 marginal areas, and armed with a pair of large hooks, 1 hook situated on each posterior ridge, and 14 marginal hooklets situated on marginal membrane. Large hooks 280 to 395μ long; marginal hooklets about 15μ long. Oral aperture at base of pseudosucker and connected with pharynx by a short funnel-like prepharynx; pharynx barrel-shaped, 425μ long by 340μ wide, intestinal branches simple, terminating near posterior end of body proper, their ends approaching but not uniting. Nervous system not observed; eyes absent. Genital aperture slightly to right of median line, about 1 mm posterior to base of pharynx. Cirrus 285 to 304μ long, relatively thick and composed of pointed longitudinal bars arranged so as to form a tubular structure; ejaculatory bulb oval, 340μ long by 255μ wide; vas deferens, before entering ejaculatory bulb, expanding and forming a pars prostatica surrounded by unicellular glands. Testis somewhat cordate, about 850μ long by 510μ wide, median, postequatorial. Ovary slender, curved, pretesticular. Vitellaria extending from level of pharynx to posterior of testis. Vagina long and relatively thick, opening ventrally on left side of body at level of common genital aperture. Ootype oval, surrounded at its base by a number of unicellular glands with long, slender ducts. Egg triangular, about 110μ wide, with relatively short filament.

Hosts.—*Dasyatis pastinaca* (Linnaeus) and *Pastinachus centrourus* (Mitchill).

Location.—Gills.

Distribution.—United States (Woods Hole, Mass.).

Specimens.—U. S. N. M. Helm. Coll. Nos. 35654 (type), 35655 (paratypes), 35656, 35657, 35658 and 35659.

MacCallum's (1916) description of this species contains several errors which are corrected in the present redescription.

MacCallum stated that "the genital pore is placed near the division of the ceca in the angle formed thereby," but his figure shows it to be situated at a point opposite the vaginal aperture, which is about 1 mm posterior to the base of the pharynx. He also stated that the cirrus had a cluster of spicules at its tip and that the mouth of the "uterus" was armed with spicules. These spicules are not present in normal specimens, but in several of the specimens prepared by MacCallum the end of the cirrus had been crushed and the pointed tips of the cuticular bars of which the cirrus is composed had become broken off, and it was these pieces which were mistaken for spicules. MacCallum described the haptor as having 8 "chitinous" ridges; actually the ridges or septa are 7 in number and are not chitinous. The posterior median ridge present in *Monocotyle* and *Heterocotyle* is entirely absent, and in this respect the haptor of *D. dasybatis* resembles that of species of *Capsala* and of the related genera *Capsaloides* and *Tristoma*.

Subfamily CALICOTYLINAE Monticelli, 1903

Diagnosis.—Anterior haptor in form of a rudimentary oral sucker; cephalic glands present, opening through a pair of ducts terminating at anterior end of body. Posterior haptor similar to that of *Monocotyle*, with 1 pair of large hooks; marginal hooklets (?). Eyes absent. Testes numerous, intercecal. Vagina double as in *Merizocotyle*.

Type genus.—*Calicotyle* Diesing, 1850.

Genus CALICOTYLE Diesing, 1850

Diagnosis.—Characters of subfamily.

Type species.—*Calicotyle kroyeri* Diesing, 1850.

The genus *Calicotyle* contains six species as follows: *Calicotyle affinis* Scott (1911), *C. australis* Johnston (1934), *C. inermis* Woolcock (1936), *C. kroyeri* Diesing (1850), *C. mitsukurii* Goto (1894) and *C. stossichi* Braun (1899). No representative of this genus has yet been reported from North America.

Subfamily MERIZOCOTYLINAE Johnston and Tiegs, 1922

Diagnosis.—Anterior haptor absent; cephalic glands present, their ducts terminating in distinct head organs. Posterior haptor with numerous sucker-like areas separated by septa, armed with 1 pair of large hooks (absent in *Empruthotrema*) and 14 marginal hooklets. Eyes present or absent. Vagina double.

Type genus.—*Merizocotyle* Cerfontaine, 1894.

KEY TO GENERA OF MERIZOCOTYLINAE

1. Termini of cephalic gland ducts forming numerous head organs. . . . . *Cathariotrema* Johnston and Tiegs

Termini of cephalic gland ducts forming 3 pairs of head organs 2
2. Haptor without large hooks ..... *Empruthotrema* Johnston and Tiegs
Haptor with 1 pair of large hooks 3
3. Haptor with 5 sucker-like depressions adjacent to central depression .....
..... *Merizocotyle* Cerfontaine
Haptor with 4 sucker-like depressions adjacent to central depression ...
..... *Thaumatocotyle* Scott

Genus MERIZOCOTYLE Cerfontaine, 1894

Diagnosis.—Anterior end of body with 3 pairs of head organs. Haptor disc-like, with a central oval or circular depression, 6 oval adjacent to central, and 18 marginal depressions, the posterior depression the largest; large hooks and marginal hooklets present. Eyes absent. Testis single.

Type species.—*Merizocotyle diaphanum* Cerfontaine, 1894.

Two species, *M. diaphanum* from *Raja batis* and *M. minus* from *R. oxyrhynchus*, have been described by Cerfontaine (1894, 1898). Neither of these species has been reported from North American hosts.

Genus THAUMATOCOTYLE Scott, 1904

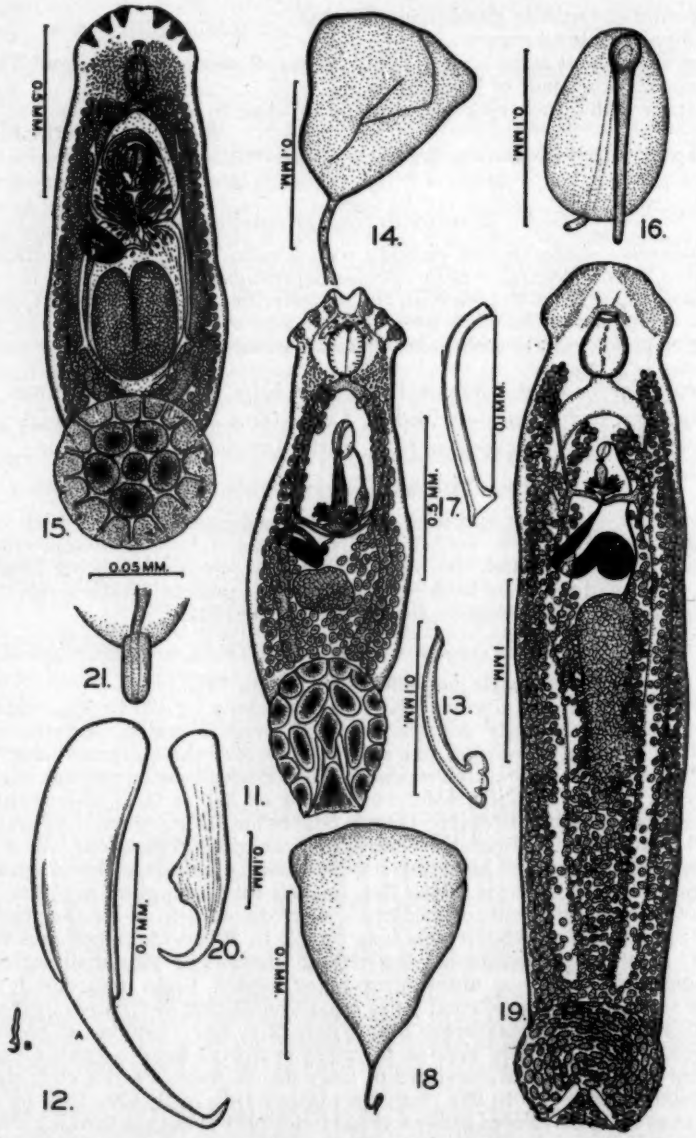
Diagnosis.—Anterior end with 3 pairs of head organs. Haptor with ventral surface divided into sucker-like depressions, 1 central, 4 adjacent to central, and 13 marginal, the posterior marginal depression being largest; large hooks and marginal hooklets present. Eyes present. Testis single.

Type species.—*Thaumatocotyle concinna* Scott, 1904.

Thaumatocotyle dasybatis (MacCallum, 1916), n. comb. Figs. 11–14

Synonym.—*Merizocotyle dasybatis* MacCallum, 1916.

Description.—Body elliptical, 1.5 to 2.6 mm long by 480 to 560μ wide in region of testis, slightly constricted in pharyngeal region. Anterior end slightly expanded, bearing 3 pairs of head organs, these organs being the openings of ducts from numerous unicellular glands located on each side of pharynx. Haptor disc-like, 440 to 600μ long by 370 to 600μ wide; ventral surface with a diamond-shaped central depression, 13 marginal depressions, and 4 depressions between the central and marginal depressions, these depressed areas separated by septa; haptor armed with 2 large hooks and 14 marginal hooklets. Large hooks 224 to 260μ long; marginal hooklets 24μ long. Oral aperture ventral, median, a short distance from anterior end of body; pharynx oval, 160 to 220μ long by 120 to 200μ wide; esophagus very short; intestinal branches simple, without median or lateral diverticula, terminating blindly near anterior margin of haptor. Brain immediately anterior to oral aperture; special sense organs consisting of 2 pairs of eyes located in the brain commissure and 1 pair of sensory papillae at anterior margin of body slightly median to anterior pair of head organs. Genital aperture median, about one-third of body length from anterior end; cirrus cuticular, tubular, 60 to 96μ long; ejaculatory bulb oval, 120μ long by 60μ wide; vas deferens dilated at level of posterior part of ootype forming a fusiform seminal vesicle. Testis irregular in shape, 120μ long by 200μ wide, postequatorial. Ovary tubular, curved, embracing right intestinal cecum, pretesticular. Vitellaria extending from level of base of pharynx to about midway between distal limit of testis and posterior end of body proper.



Figs. 11–14.—*Thaumatocotyle dasybatis.* 11, complete worm, ventral view; 12, haptoral hooks (A—large hook, B—marginal hooklet); 13, cirrus; 14, egg. Figs. 15–18.—*Empruthotrema raiae.* 15, complete worm, ventral view; 16, cirrus and ejaculatory bulb; 17, cirrus; 18, egg. Figs. 19–21.—*Cathariotrema selachii.* 19, complete worm, ventral view; 20, large haptoral hook; 21, cirrus.

Paired vaginae; vaginal apertures ventral, one in vicinity of each intestinal cecum about midway between anterior end and posterior end of body proper. Ootype elongate, muscular, surrounded at its base by numerous unicellular glands with long, slender ducts. Egg triangular, about 100μ wide, with a relatively long slender filament at apex.

Hosts.—*Dasyatis pastinaca* (Linnaeus), *Pastinachus centrourus* (Mitchill) and *Raja erinacea* Mitchill.

Location.—Olfactory organs and gills.

Distribution.—United States (Woods Hole, Mass.)

Specimens.—U. S. N. M. Helm. Coll. Nos. 27553 (cotypes), 35098, 35114, 35163, 35184, 35243, 35659, 35660, 35661, 35662, 35663, 35664, and 35665.

Thaumatocotyle dasybatis appears to be closely related to, if not identical with *Thaumatocotyle concinna* Scott, 1904, from the nasal fossae of "*Trygon pastinaca*" in Scotland. Scott's (1904) description of *T. concinna* was very inadequate as was his figure of the species. However, assuming that the illustration is accurate, the only difference between that form and *T. dasybatis* is in the size of the pharynx, which in *T. concinna* is about one-fifth of the length of the body proper, while in *T. dasybatis* it is about one-tenth of the length of the body proper.

Genus EMPRUTHOTREMA Johnston and Tiegs, 1922

Diagnosis.—Anterior end with 3 pairs of head organs. Haptor with ventral surface divided by septa into sucker-like depressions, 1 central, 5 adjacent to central, and 14 marginal; large hooks absent, marginal hooklets present. Eyes absent. Testis double.

Type species.—*Empruthotrema raiae* (MacCallum, 1916) Johnston and Tiegs, 1922.

Empruthotrema raiae (MacCallum, 1916) Johnston and Tiegs, 1922

Figs. 15–18

Synonym.—*Acanthocotyle raiae* MacCallum, 1916.

Description.—Body elongate, more or less rectangular, 1.6 to 2 mm long by 528 to 700μ wide, anterior end with 3 pairs of head organs, and with numerous unicellular glands on each side of pharynx. Haptor circular, 450 to 575μ in diameter, with a central sucker-like area, 5 similar areas adjacent to central area and 14 marginal areas, all separated from each other by septa; with no large hooks, but with 14 marginal hooklets each about 16μ long. Oral aperture median, ventral, about 100μ from anterior end of body; pharynx 96 to 120μ long by 80 to 96μ wide; esophagus very short; intestinal ceca simple, extending to near posterior end of body proper, tips approaching each other. Nervous system not observed; eyes absent. Genital aperture median, ventral, about one-third of body length from anterior end. Cirrus tubular, cuticular, 120 to 135μ long; ejaculatory bulb oval, 104 to 120μ long by 72 to 80μ wide; distal end of vas deferens expanded and with muscular walls, curving around anterior end of ejaculatory bulb and entering it from right side. Testis double, postequatorial. Ovary sharply curved, embracing right intestinal cecum, equatorial. Vitellaria largely in cecal fields, extending from level of posterior end of esophagus to near posterior end of body proper, with band of follicles crossing median field distal to testis. Paired vaginae as in *Merizocotyle*. Ootype piriform, widest anteriorly, its posterior end surrounded by numerous unicellular glands having long, slender ducts. Egg more or less triangular, about 120μ wide, with relatively short filament.

Hosts.—*Raja erinacea* Mitchill and *R. diaphanes* Mitchill.
Location.—Olfactory organs.
Distribution.—United States (Woods Hole, Mass.).
Specimens.—U. S. N. M. Helm. Coll. Nos. 35160, 35172, 35666, 35667, and 35668.

This species was originally described as belonging to the genus *Acanthocotyle*, but, as Johnston and Tiegs (1922) have pointed out, it is not congeneric with species of that genus. A number of specimens were available to the writer, and a study of these specimens showed that the original description is accurate in most respects. MacCallum stated that there were 2 testes in this species, but instead of 2 testes there appears to be a single testis which is folded in approximately a U-shape. In the original description the size of the egg was given as 20μ, while the writer's measurements show that it is about 120μ wide; however, no very accurate measurements could be obtained as all the eggs present were uterine eggs and had become considerably distorted during the process of dehydration and clearing.

Genus CATHARIOTREMA Johnston and Tiegs, 1922

Synonym.—*Paramonocotyle* Johnston, 1934.
Diagnosis.—Anterior end with numerous gland termini along margins, not in form of head organs as in *Merizocotyle*. Haptor disc-like, wider than long, with its ventral surface divided into a large number of sucker-like depressions; large hooks and marginal hooklets present. Eyes absent. Testis single.
Type species.—*Catharіotrema selachii* (MacCallum, 1916) Johnston and Tiegs, 1922

Catharіotrema selachii (MacCallum, 1916) Johnston and Tiegs, 1922
Figs. 19–21

Synonym.—*Monocotyle selachii* MacCallum, 1916; *Paramonocotyle selachii* (MacCallum, 1916) Johnston, 1934.
Description.—Body elongate, 4.7 mm long by 880μ wide, lateral margins almost parallel, with slight constriction at level of pharynx. Anterior haptors in form of a glandular area on each side of anterior end, the glands opening through numerous duct apertures along margins. Posterior haptor disc-like, 496 to 640μ long by 768 to 825μ wide, its ventral surface divided by septa into numerous oval depressions, armed with 2 large, robust hooks directed postero-laterally and a number (?14) of marginal hooklets. Large hooks 200 to 310μ long; marginal hooklets about 12μ long. Oral aperture ventral, median, about 300μ from anterior end of body; pharynx piriform, 320 to 336μ long by 240 to 280μ wide; esophagus very short; intestinal ceca simple, extending to near anterior margin of posterior haptor. Brain immediately anterior to oral aperture; eyes absent. Genital aperture median, about 400μ posterior to base of pharynx. Cirrus cuticular, about 40μ long; ejaculatory bulb about 128μ long by 80μ wide. Testis elongate, in equatorial zone. Ovary S-shaped, embracing right intestinal cecum; vitellaria extending from level of base of pharynx to posterior end of body, meeting in median line distal to testis. Paired vaginae as in *Merizocotyle*. Ootype oval, relatively small, its base surrounded by numerous unicellular glands having long slender ducts. Egg not observed.

Hosts.—*Carcharias obscurus* (Le Sueur), *C. commersonii* (Blainville), *Sphyrna zygaena* (Linn.) and *Alopias vulpinus* (Bonnaterre).
Location.—Olfactory organs.
Distribution.—United States (Woods Hole, Mass.).
Specimens.—U. S. N. M. Helm. Coll. Nos. 35669 (type), 35670, 35671, 35672, 35673, and 35674.

Johnston and Tiegs have shown that this species does not belong in the genus *Monocotyle* where it was placed by MacCallum, and append it to the Calceostominae. Their action in this case was based on a study of the original description and figures which were from mutilated specimens. The "head-lobes" which these writers regarded as showing affinities with *Calceostoma* do not exist, the figure given by MacCallum being of a crushed specimen.

Subfamily LOIMOINAE Price, 1936

Diagnosis.—Anterior haptor in form of 4 small preoral suckers; posterior haptor disc-like, terminal, without septa, with 1 pair of large hooks and a number (?14) of marginal hooklets. Genital aperture apparently median or submedian; cirrus long, slender, cuticular; testis single. Ovary apparently globular; vagina?
Type genus.—*Loimos* MacCallum, 1917.

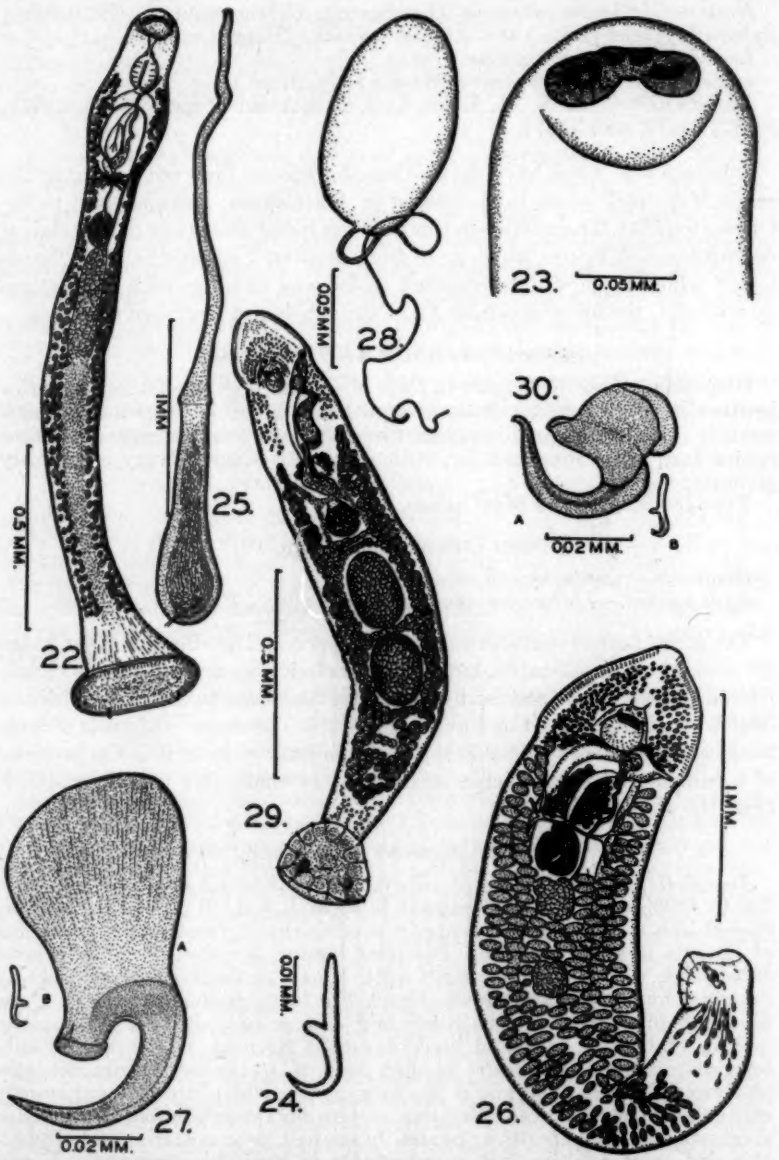
Genus LOIMOS MacCallum, 1917

Diagnosis.—Characters of subfamily.
Type species.—*Loimos salpinggoides* MacCallum, 1917.

The genus *Loimos* contains only the type species. The affinities of the genus are somewhat questionable, but on the whole it appears to be more closely related to members of the family Monocotylidae than to the family Udonellidae where it was placed by Fuhrmann (1928). The presence of a pair of large hooks and of small hooklets on the posterior haptor, as well as the presence of a tubular, heavily cuticularized cirrus are characters which exclude it from the Udonellidae.

Loimos salpinggoides MacCallum, 1917 Figs. 22–25

Description.—Body elongate, subcylindrical, 2 to 4.5 mm long by about 220 to 4000μ wide. Anterior haptors in form of 4 small preoral suckers arranged in a transverse row, centrals, smaller than laterals and usually one of laterals larger than other. Posterior haptor disc-like, terminal, about 460μ wide, without septa, armed with 1 pair of large hooks and (?) 14 marginal hooklets. Large hooks about 40μ long, similar in form to those occurring on species of *Monocotyle* and *Heterocotyle*, situated at posterior margin of haptor; marginal hooklets about 8μ long. Oral aperture subterminal, about 120μ wide, leading into a somewhat funnel-like prepharynx; pharynx oval, about 80μ long by 65μ wide; intestine apparently consisting of simple ceca. Nervous system not ascertainable in available specimens. Genital aperture apparently median, near posterior end of pharynx, its exact position not ascertainable in available specimens. Cirrus slender, tubular, about 220μ long; ejaculatory bulb elongate, about 95μ long by 30μ wide. Testis single, median, preequatorial. Ovary apparently



Figs. 22–25.—*Loimos salpinggoides.* 22, complete worm, ventral view; 23, anterior end of body, ventral view; 24, large haptoral hook; 25, cirrus. Figs. 26–28.—*Dionchus agassizi.* 26, complete worm, ventral view; 27, haptoral hooks (A—large hook, B—marginal hooklet); 28, egg. Figs. 29–30.—*Dionchus remorae.* 29, complete worm, ventral view; 30, haptoral hooks (A—large hook, B—marginal hooklet).

globular, pretesticular. Vitellaria lateral, extending from level of posterior end of pharynx to near posterior end of body. Vagina (?). Ootype elongate, its base surrounded by unicellular glands with relatively long ducts. Egg oval, 130μ long by 65μ wide, with relatively short filament at posterior pole.

Host.—*Carcharias obscurus* (Le Sueur).

Location.—Gills.

Distribution.—United States (Woods Hole, Mass.)

Specimens.—U. S. N. M. Helm. Coll. 35675 (cotypes).

This rather remarkable trematode was collected by MacCallum at Woods Hole, Mass., August 7, 1916, from the gills of a dusky shark. About 40 of the original specimens (all toto mounts) were available for study, but unfortunately the technique employed in their preparation had distorted most of the specimens so that many of the characters could not be accurately ascertained. A study of these specimens revealed several inaccuracies in the original description (MacCallum, 1917), the most outstanding being the location of the genital aperture, the number of testes, size of the large hooks, and size of the egg. The genital aperture is shown by MacCallum to be on the left side and about the level of the anterior end of the pharynx; no trace of a genital aperture was found in that location and all indications point to its location in median line posterior to the pharynx. In a few specimens the end of the cirrus was in the position indicated by MacCallum but such specimens were more or less crushed and the rather heavy cuticularized cirrus could easily have been forced into the position indicated. There is only 1 testis in this species; it is rather long and cylindrical, and in no specimen was there any indication of 2 testes as shown by MacCallum. The large hooks are about 4 times as long as given in the original description, and the egg more than twice as large. No trace of an excretory pore was observed at the posterior end of the body as indicated in the original description, and it seems reasonable to assume that the excretory apertures are towards the anterior end of the body as in other monogenetic trematodes.

Subfamily DIONCHINAE Johnston and Tiegs, 1922

Diagnosis.—Anterior haptor absent, numerous cephalic glands opening along margin of anterior end of body. Posterior haptor sucker-like, ventral surface with septa, with 1 pair of large hooks and 14 marginal hooklets. Intestinal branches simple, united posterioriy. Eyes present. Genital aperture sinistral, submarginal. Cirrus muscular, unarmed. Two testes, tandem. Vagina absent.

Type genus.—*Dionchus* Goto, 1899.

This subfamily contains only the genus *Dionchus* Goto, and was included by Johnston and Tiegs (1922) in the family Calceostomidae mainly because the cephalic gland ducts did not open through "head organs" as in the case of most of the members of the Monocotylidae. However, the presence of "head organs" is not constant in the Monocotylidae and this character alone does not seem sufficient to exclude *Dionchus* from that family.

Genus DIONCHUS Goto, 1899

Synonyms.—*Acanthodiscus* MacCallum, 1916, not MacCallum, 1918, not Uhlig, 1906 (mollusk); *Dionchotrema* Johnston and Tiegs, 1922.

Diagnosis.—Characters of subfamily.

Type species.—*Dionchus agassizi* Goto, 1899.

This genus contains only two species, both of which are described below.

Dionchus agassizi Goto, 1899 Figs. 26–28

Description.—Body elongate, 2.2 to 2.8 mm long by 630 to 765μ wide; anterior end triangular, with slight constriction slightly posterior to level of base of pharynx. Anterior haptor absent, but with numerous adhesive glands almost filling anterior end and opening along margins of body anterior to constriction. Posterior haptor sucker-like, divided into 10 marginal areas by as many septa, and armed with 1 pair of large hooks and 14 marginal hooklets; large hooks 95μ long, with strongly curved, pointed tips; marginal hooklets about 15μ long. Numerous large unicellular glands anterior to haptor, with long ducts apparently opening into cavity of haptor. Oral aperture ventral, median, about 340 to 400μ from anterior end of body. Pharynx globular, 95 to 190μ long by 114 to 210μ wide; esophagus very short, with groups of esophageal glands extending laterally; intestinal branches without diverticula, uniting about one-third of body length from posterior end. Brain anterior to oral aperture; 2 pairs of eyes. Genital aperture sinistral, near margin of body; genital atrium large, more or less globular. Cirrus small, muscular; vas deferens wide, more or less convoluted. Testes 2 in number, tandem; anterior testis about 210μ in diameter, posterior testis about 170μ in diameter, separated by relatively wide band of vitelline follicles. Ovary U-shaped, pretesticular, median. Vitelline follicles large, extending from slightly posterior to level of genital aperture to about 500μ from posterior end of body. Vagina absent. Ootype tubular, its base surrounded by relatively large unicellular glands with long ducts; lateral to ootype are large unicellular glands having less affinity for stain than those at base of ootype. Egg oval, 106μ long by about 60μ wide, with long slender filament at one pole.

Hosts.—*Remoropsis brachyptera* (Lowe) and *Echeneis naucrates* Linnaeus.

Locality.—Gills.

Distribution.—United States (New York, N. Y., Newport, R. I., and Woods Hole, Mass.) and West Indies.

Specimens.—U. S. N. M. Helm. Coll. Nos. 35676, 35677, and 35678.

This species was originally described by Goto (1899) from *Remora brachyptera* (= *Remoropsis brachyptera*) and apparently has not been reported since. Seven specimens, representing collections made August 2, 1915, May 4, 1915, and July 10, 1922, are in the U. S. National Museum and were obtained by MacCallum from *Echeneis naucrates* at the New York Aquarium and at Woods Hole, Mass. Several additional specimens, mostly immature, were collected in 1933 by the Johnson-Smithsonian Deep-Sea Expedition from the latter host in West Indian waters.

Dionchus remorae (MacCallum, 1916), n. comb. Figs. 29–30

Synonyms.—*Acanthodiscus remorae* MacCallum, 1916, *Dionchotrema remorae* (MacCallum, 1916) Johnston and Tiegs, 1922.

Description.—Body elongate, about 1.5 mm long by 290μ wide, anterior end rounded and with slight constriction at level of pharynx, posterior part of body slightly attenuated. Anterior haptors absent; cephalic glands numerous, opening along anterior margin of body. Posterior haptor sucker-like, about 220μ in diameter; ventral surface divided into 14 marginal areas by as many septa, armed with 1 pair of large hooks and 14 marginal hooklets. Large hooks 35 to 50μ long, with strongly curved, pointed tips; marginal hooklets 18μ long. Oral aperture ventral, median, about 150μ from anterior end of body; pharynx globular, about 57μ in diameter; intestinal tract not observed. Brain anterior to oral aperture; eyes present, 2 pairs. Genital aperture sinistral, submarginal, slightly anterior to level of oral aperture; genital sinus relatively small. Cirrus short, bulbous, muscular and unarmed. Vas deferens widened distally, forming a tortuous seminal vesicle. Testes oval, tandem, postequatorial; anterior testis 200μ long by 135μ wide; posterior testis 190μ long by 135μ wide, separated from anterior testis by a narrow band of vitelline follicles. Ovary apparently globular, median, separated from anterior testis by a relatively wide band of vitelline follicles. Vitellaria consisting of relatively large follicles, extending from slightly anterior to base of ootype to a short distance from posterior end of body proper. Vagina absent. Ootype slender, relatively long, its base surrounded by a number of unicellular glands having long, slender ducts. Eggs not observed.

Hosts.—*Echeneis naucrates* Linnaeus and *Caranx hippos* (Linnaeus).

Location.—Gills.

Distribution.—United States (New York, N. Y.) and West Indies.

Specimens.—U. S. N. M. Helm. Coll. Nos. 35679 (type), 35680 (paratypes), 35681, 35682, and 35683.

Dionchus remorae was described by MacCallum (1916) as *Acanthodiscus remorae*. Johnston and Tiegs (1922) noted that the genus *Acanthodiscus* to which MacCallum assigned the species was preoccupied, the name having been used by Uhlig in 1906 for a genus of mollusks. These writers recognized the close relationship of the species to *Dionchus*, but owing to the fact that MacCallum figured the species as having a vagina they regarded it as distinct and placed it in a new genus *Dionchotrema*. An examination of MacCallum's original specimens shows that a vagina is absent and the species, therefore, is transferred to the genus *Dionchus*.

The material available to the writer consisted of a number of specimens collected by MacCallum from *Echeneis naucrates* at the New York Aquarium May 16, 19, 29, and 30, 1915, and one specimen from *Caranx hippos* collected May 8, 1915. In addition to this material, several immature specimens were available which had been collected in 1933 by the Johnson-Smithsonian Deep-Sea Expedition from 2 specimens of *Echeneis naucrates* taken in West Indian waters.

In restudying this species, several errors have been detected in the description as given by MacCallum. According to that author, the mouth is terminal, the genital atrium and cirrus are armed, and a vagina is present; however, the present writer finds the mouth to be ventral, the genital atrium and cirrus unarmed, and there is no vagina.

Dionchus remorae is closely related to *Dionchus agassizi* but may be easily distinguished from the latter species by its smaller size, by its more rounded anterior end, by the extent of the vitellaria anteriorly, and by the number of marginal areas of the haptor.

(To be continued)

ENTOMOLOGY.—*A study of the North American ants of the genus* Xiphomyrmex *Forel.*[1] MARION R. SMITH, Bureau of Entomology and Plant Quarantine. (Communicated by C. F. W. MUESEBECK.)

The genus *Xiphomyrmex* Forel, formerly considered as a subgenus of *Tetramorium* Mayr, includes 50 to 75 forms. Species occur in Africa, Madagascar, Indo-Malaya, Australia, and the Sonoran region of North America. According to Wheeler these ants nest in the ground, often forming populous colonies. The following is a translation of Emery's characterization of the genus in Genera Insectorum:

Worker.—Anterior border of clypeus feebly emarginate, the lateral border forming an elevated ridge in front of the antennal fossa. Frontal carinae well separated. Antenna 11-segmented. Antennal scrobe well developed. Hairs simple or clavate.

Queen.—Usually larger than the worker, but similar in structure of head, petiole, and hairs. Antenna 11-segmented. Anterior wing with the radial cell usually closed.

Male.—Mandibles toothed. Antenna 10-segmented, the second funicular segment long and composed of the fused segments 2, 3, 4, 5. Wings as in the queen.

This paper deals with four forms of *Xiphomyrmex* known to occur only in the southwestern section of the United States, and Northern Mexico. These four forms are the species *X. spinosus* and its subspecies *insons*, *hispidus*, and *wheeleri*. The typical form was described by Pergande from 14 workers collected at Sierra, San Lazaro, Cape Region, Lower California, and is known only from these specimens. The subspecies *insons* has been recorded from Texas and Arizona (Wheeler), *wheeleri* from Arizona and Mexico (Wheeler), and *hispidus* from Arizona (Wheeler). The worker of *X. spinosus* bears such a striking resemblance to that of *Tetramorium guineense* (F.) that the two could easily be confused except by careful examination. It differs, however, in the number of antennal segments, the number of carinae on the clypeus, the shape of the petiole and postpetiole, the shape of the humeral angles of the prothorax, etc.

[1] Received December 30, 1937.

In preparing this article I have been fortunate in being able to study cotypes of all four forms. I wish to express my thanks to the American Museum of Natural History and the Museum of Comparative Zoology for the loan of cotypes, and to Dr. W. S. Creighton for the loan of specimens from his personal collection.

My studies have shown that the subspecies of *spinosus* represent extreme variations, and that there are other forms intermediate between the named forms. The existence of these intermediates might justify the synonymizing of the subspecies with the typical form; but, since many recognized subspecific forms of ants are based on characters of no greater strength than those separating the subspecies of *X. spinosus* from the typical form, I prefer to retain these forms as distinct.

Because Pergande's original description of the species is incomplete I have redescribed *X. spinosus* on the basis of type material in the collection of the United States National Museum. The descriptions of the three subspecies consist only of statements of the characters by which they differ from the typical form. Males and queens of the various subspecies have not been available for study.

The key below should serve to distinguish the workers of the various forms of *spinosus*.

KEY TO THE FORMS OF XIPHOMYRMEX SPINOSUS PERGANDE
(for the identification of the workers)

1. First gastric segment finely punctulate, shagreened, subopaque toward the base 2
   First gastric segment entirely smooth, except for scattered, piligerous punctures 3
2. Erect hairs on the head and thorax long, slender, and tapering; metasternal angles acute, spine-like ..... *spinosus* Pergande
   Erect hairs on the head and thorax short, coarse, and blunt; metasternal angles blunt, not spine-shaped ..... subsp. *hispidus* Wheeler
3. Metasternal angles acute, spiniform; thorax viewed from above with indistinct mesoepinotal constriction ..... subsp. *insons* Wheeler
   Metasternal angles blunt, not spine-like; thorax viewed from above with a distinct mesoepinotal constriction ..... subsp. *wheeleri* (Forel)

Xiphomyrmex spinosus Pergande

Xiphomyrmex spinosus Pergande, Proc. Calif. Acad. Sci., Vol. 5, p. 894 (1895). *Worker.* Mexico.

Worker.—Length 3.2–3.4 mm.

Head, excluding mandibles, subrectangular, slightly longer than broad, with moderately convex sides, rounded occipital angles, and faintly emarginate posterior border. Eye prominent, oval, convex, placed a little more than its greatest diameter from the base of the mandibles. Mandible triangular, moderately convex dorsally, and with 7 or 8 distinct teeth. Clypeus

convex, posterior border broadly rounded and extending between the frontal carinae, anterior border very faintly emarginate or impressed medianly. Antenna 11-segmented, the scape distinctly compressed, and when lying in the antennal scrobe made on each side of the head by the frontal carina, not reaching the posterior border of the head; funiculus with a distinct 3-segmented club, which is apparently as long as the remainder of the funiculus. Pronotum from above with broadly rounded humeral angles. Mesoepinotal constriction faint. Epinotal spines prominent, straight, and acute, directed backward and gradually divergent; scarcely longer than the dis-

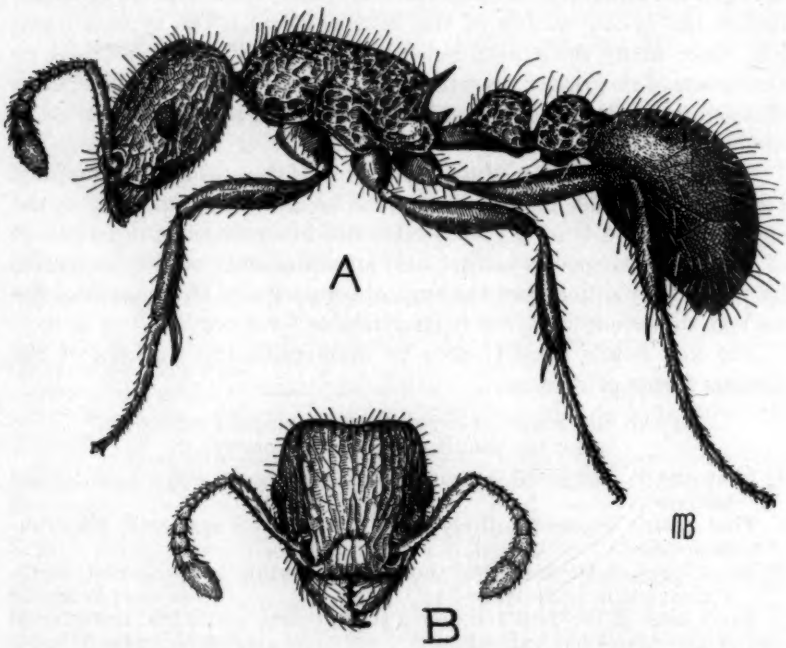


Fig. 1.—*Xiphomyrmex spinosus* Pergande, worker. A, lateral view of body; B, frontal view of head. Illustrations by Mrs. Mary F. Benson.

tance between their bases. Metasternal angles distinct, tooth-like, acute, at least one-half the length of the epinotal spines. Petiole viewed directly from above subcampanulate, postpetiole viewed from the same aspect transversely elliptical. Gaster oval, without pronounced basal angles.

Mandibles with moderately coarse, longitudinal striae. Clypeus with 6 to 8 prominent longitudinal striations, some of which are not complete. Head, thorax, petiole, and postpetiole coarsely rugose-reticulate, the interspaces finely punctulate. The rugae in the center of the head and thorax with a more nearly longitudinal trend than elsewhere. Gaster smooth and shining except for the first segment, the basal half of which is finely punctulate, shagreened, and therefore subopaque.

Hairs rather abundant over all parts of the body; yellowish, erect, but of varying lengths; those on the appendages shorter, and suberect.

Ferruginous; mandibles, clypeus, and legs noticeably lighter.

The above description is based on 7 cotype specimens collected at Sierra, San Lazaro, Cape Region, Lower California, all of which are in the collections of the National Museum.

Xiphomyrmex spinosus subsp. *hispidus* Wheeler

Xiphomyrmex spinosus subsp. *hispidus* Wheeler, Bull. Amer. Mus. Nat. Hist., Vol. 34, p. 415 (1915). *Worker*. Arizona.

Worker.—Length 3.5—3.8 mm.

Posterior border of head very distinctly emarginate. Antennal funiculus not infuscated distally. Metasternal angles blunt, not spineshaped. First segment of the gaster finely punctulate, shagreened and subopaque toward the base. Hairs short, coarse, blunt, and of unequal length.

Description based on 5 cotype specimens labeled "Desert, east of Tucson, Arizona; W. M. Wheeler" (Amer. Mus. Nat. Hist. and Museum of Comp. Zoology).

Wheeler states that he found these ants "nesting in small craters 3 to 4 inches in diameter, in the deserts around Tucson, Arizona (type locality), and from Phoenix in the same state."

Xiphomyrmex spinosus subsp. *insons* Wheeler

Xiphomyrmex spinosus subsp. *insons* Wheeler, Bull. Amer. Mus. Nat. Hist., Vol. 34, p. 416 (1915). *All castes*. Texas, Arizona.

Worker.—Length 3.5–4 mm.

Posterior border of head emarginate but not so strongly as in *wheeleri*. Antennal funiculus not infuscated distally. Mesoepinotal constriction, viewed from above, very weak, scarcely apparent. Metasternal angles acute, spine-like. Gaster smooth and shining except for scattered piligerous punctures. Hairs long and slender, and of unequal lengths; on the tibiae shorter than in *wheeleri*.

Description based on 3 cotype specimens labeled "Austin, Texas; W. M. Wheeler" (Amer. Mus. Nat. Hist.).

Wheeler cites Austin, Texas, as the type locality, and lists the species from the following other localities:

Texas.—New Braunfels, Alamito in Brewster County, Alice, San Angelo, Fort Davis, Kennedy, Langtry, Barksdale and Del Rio.

Arizona.—Miller Canyon (Huachuca Mts.).

I have referred to this subspecies 3 workers taken from the stomach of an armadillo at Junction, Texas, and submitted by the Bureau of Biological Survey, United States Department of Agriculture.

Wheeler, in remarking on the habits of this species, says, "This ant nests in small craters in dry, grassy places. There are scarcely more than 70 individuals in a colony. The workers are very timid and forage singly. The winged phases appear during the first week in June."

Xiphomyrmex spinosus subsp. *wheeleri* (Forel)

Tetramorium (*Xiphomyrmex*) *wheeleri* Forel, Ann. Soc. Ent. Belg., Vol. 45, p. 128 (1901). *Worker.* Mexico.

Xiphomyrmex spinosus subsp. *wheeleri* (Forel) Wheeler, Bull. Amer. Mus. Nat. Hist., Vol. 34, p. 416 (1915). *Worker.*

Worker.—Length 3.5–3.7 mm.

Posterior border of head faintly emarginate. Antennal club distinctly infuscated. Thorax, viewed from above, with a very distinct mesoepinotal constriction. Metasternal angles blunt, not spine-like. Gaster smooth and shining except for the scattered piligerous punctures. Hairs on the tibiae apparently longer and more reclinate than with *spinosus*.

Description based on 3 cotypes from the type locality, Pacheco, Zacatecas, Mexico; W. M. Wheeler (Amer. Mus. Nat. Hist.).

Wheeler states that he took in the Miller Canyon (Huachuca Mts., Ariz.) specimens of a form closely related to *wheeleri* but differing in the size of the epinotal spine, type of rugosity of postpetiole, and infuscation of the antennal club. I have seen specimens from the Ramsey Canyon of the same mountains which seem to belong to this undescribed form mentioned by Wheeler. These were taken by Dr. W. S. Creighton.

Wheeler apparently collected his type specimens from a small colony beneath a stone in the cactus desert.

PALEOBOTANY.—*Two fossils misidentified as shelf-fungi.*[1] ROLAND W. BROWN, U. S. Geological Survey.

In 1936 I described *Polyporites stevensoni* Brown[2] as a Cretaceous shelf-fungus. This specimen megascopically, and in such microscopic details as are preserved, resembles very closely a living species of shelf-fungus growing on *Eucalyptus* in Australia. Recently, however, a chance observation of some Paleozoic corals of the syringopore group caused me to reexamine the supposed fungus with the result that I am now chagrined to admit that *Polyporites stevensoni* is not a fungus but a syringopore coral of probably undeterminable species. Evidently the specimen, which I considered as indigenous to the flora preserved in Upper Cretaceous strata along the Cannonball River in southwestern North Dakota, was a pebble that had been transported from some Paleozoic source far to the west.

The description of *Polyporites stevensoni* followed a precedent set by *Polyporites browni* Wieland[3] as stated in my paper. The mistake in regard to *P. stevensoni*, therefore, aroused suspicions with respect to

[1] Received February 21, 1938.

[2] This JOURNAL **26**: 460-462. 1936.

[3] WIELAND, G. R. *A silicified shelf fungus from the Lower Cretaceous of Montana.* Am. Mus. Nov. **725**: 1-13. 1934.

P. browni, which, however, is said to have been collected from the Cloverly formation (Lower Cretaceous) exposed along Beauvais Creek, 40 miles south of Billings, Mont. Through the courtesy of Dr. Barnum Brown and the American Museum of Natural History I have been permitted to reexamine that specimen. A chemical analysis by E. P. Henderson of the National Museum showed a high percentage of phosphate radical, which is strong, presumptive evidence that the fossil is a bone, not a fungus. With this hypothesis in mind, and with the rather distinctive surface and internal structure of the specimen as a guide, a search with C. W. Gilmore through the National Museum vertebrate collections resulted in the elimination of every available possibility except the dental plates of Jurassic and Cretaceous species of the lung-fish, *Ceratodus*. The correspondence, detail for detail, with these remains is so close that there is little, if any, doubt that *Polyporites browni* represents *Ceratodus*. The specimen is therefore renamed *Ceratodus browni* (Wieland) Brown, n. comb.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

CHEMICAL SOCIETY

494TH MEETING

The 494th Meeting was held in the Auditorium of the George Washington University School of Medicine on Thursday, October 14, 1937, President NICOLET presiding.

The program was presented in three sections as follows:

ANALYTICAL and INORGANIC CHEMISTRY, A. R. MERZ presiding.:

JOHN W. KNOWLTON and FREDERICK D. ROSSINI: *Method and apparatus for the rapid conversion of deuterium oxide into deuterium.*—A glass bulb at one end of the evacuated conversion apparatus contains a sealed ampoule holding the liquid deuterium oxide. This ampoule of "heavy" water is broken by placing liquid air around the outer bulb, which is subsequently heated electrically to control the passage of the vapors of deuterium oxide into the reaction tube, containing powdered magnesium at 480°C, where the following reaction occurs:

$$Mg(solid) + D_2O(gas) = MgO(solid) + D_2(gas).$$

The rate of evolution of deuterium can be made as great as one mole in two hours. The evolved deuterium passes through a liquid air trap and is collected as liquid in a 0.05 liter brass bottle immersed in ordinary liquid hydrogen (temperature about −253°C). The connection to the conversion apparatus is closed, that to a 1 liter brass bottle is opened, and the deuterium is permitted to vaporize and fill two brass bottles at room temperature. In this manner 95 percent of the deuterium is obtained in the 1 liter bottle as a gas under a pressure of about 23 atmospheres. (*Authors' Abstract*)

HERMAN J. MORRIS and HERBERT O. CALVERY: *The quantitative determination of arsenic in small amounts in biological materials.*

RALEIGH GILCHRIST: *A new procedure for the analysis of dental gold alloys.*

ORGANIC and BIOLOGICAL CHEMISTRY, N. L. DRAKE presiding:

M. X. SULLIVAN: *New Tests in the guanidine field.*—It has long been known that guanidine and methylated guanidine are more or less toxic to man, but what part they might play in health and disease has been problematical since satisfactory tests have been lacking. In a study of the various guanidine compounds, Sullivan devised colorimetric tests, highly specific for simple guanidine $NH=C(NH_2)_2$ and for unsymmetrical dimethyl-guanidine $NH=C\begin{smallmatrix}NH_2\\N(CH_3)_2\end{smallmatrix}$. It was demonstrated that guanidine reacts on warming with beta-naphtho-quinone-4-sodium sulfonate and dilute NaOH to give a brown color which on cooling and acidifying with conc. HCl and HNO_3 goes to bright red while all other biologically important substances so far tested go to bright yellow. The test is readily sensitive to 0.5 mg of guanidine per cc. The test for unsymmetrical dimethyl-guanidine depends on the finding that of all the substances which react with acetyl benzoyl and alkali, unsymmetrical dimethylguanidine (1 mg per cc) is the only one so far met with that is not discharged to colorless on warming for 1 min. with 0.5 cc 3% H_2O_2. The color remains brownish due to a faint precipitate, and on addition of alcohol or toluene goes to an intense purple, while all other complexes are colorless. Application is being made of these tests in various diseases, such as muscular distrophy and hypertension. (*Author's Abstract.*)

SANFORD M. ROSENTHAL: *Chemical compounds active against bacterial infections.*—A review of recent advances in bacterial chemotherapy with a discussion of the active chemical radicals involved was given. Various modifications of the sulfanilamide molecule in relation to chemotherapeutic effect were shown. New compounds including di-sulfanilamide and the diphenyl sulfones, of superior therapeutic action, were presented. (*Author's Abstract.*)

V. DU VIGNEAUD, G. W. IRVING, H. M. DYER, R. R. SEALOCK: *The differential migration of the blood-pressure-raising and the uterine-contracting hormones of the posterior lobe of the pituitary.*—(The complete article is in press, to be published in the Journal of Biological Chemistry).

C. E. SANDO: *Exhibit: The preservation of agricultural specimens in plastics.*—One portion of this exhibit represented plant materials such as roots, stalks, stems, leaves and flowers, which had been treated chemically in such a manner as to toughen the tissues and set the natural color, after which they were preserved between transparent cellulose acetate sheets. These specimens were prepared by Mr. G. R. Fessenden. The second portion of the exhibit prepared by Dr. Sando consisted of specimens such as seeds, beetles and flowers, imbedded in methacrylates. The three outstanding methacrylate specimens were an ear of corn, which in its imbedded state measured $2\frac{1}{4}'' \times 3'' \times 7''$, an iridescent butterfly, mounted by a process which prevented actual contact between the specimen and the methacrylate, and an imbedded group of red globe amaranth flowers. (*Author's Abstract.*)

PHYSICAL CHEMISTRY, S. B. HENDRICKS presiding:

STEPHEN BRUNAUER, PAUL H. EMMETT and EDWARD TELLER: *Adsorption of gases in multimolecular layers.*—A derivation of an isotherm equation for adsorption of multimolecular layers was carried out on the assumption that the same forces which produce condensation are also responsible for multi-

molecular adsorption. The method of derivation was a generalization of Langmuir's derivation of the isotherm equation for unimolecular layers. The equation is

$$(A) \qquad v = v_m c \frac{x}{1-x} \frac{1-(n+1)x^n+nx^{n+1}}{1+(c-1)x-cx^{n+1}}$$

where v is the volume adsorbed at pressure p; x equals p/p_0, p_0 being the saturation pressure; v_m is the volume of gas required to form a unimolecular layer on the adsorbent; c is approximately $e^{(E_1-E_L)/RT}$, E_1 being the heat of adsorption in the first layer and E_L the heat of liquefaction of the gas; and n is the maximum number of layers that can build up on the adsorbent. For small values of x or large values of n the equation reduces to the linear form

$$(B) \qquad \frac{p}{v(p_0-p)} = \frac{1}{v_m c} + \frac{c-1}{v_m c} \cdot \frac{p}{p_0}$$

Equations (A) and (B) were applied to numerous experimental adsorption isotherms obtained by other investigators as well as by the authors. The equations seem to represent in a satisfactory manner not only the shape of low temperature van der Waals adsorption isotherms, but also their temperature dependence. Values obtained for v_m were in good agreement with those previously estimated empirically directly from the low temperature adsorption isotherms. (*Authors' Abstract.*)

F. W. ROSE, JR: *Quantitative analysis, with respect to the component structural groups, of the infra-red (1 to 2 mu) molal absorptive indices of fifty-four hydrocarbons.*—Data from the previous studies on the infra-red absorption spectra between 1.2 and 1.8μ (5400 to 8900 cm^{-1}) for 54 hydrocarbons have been correlated. The total molal absorptive index, K, at any wave length, is shown to follow, within the limits necessary to define the number of groups, the formula

$$K = n_a\alpha + n_b\beta + n_c\gamma + n_d\delta$$

where n_a, n_b, n_c, n_d are the number of $-CH_3$, $>CH_2$, $\geqslant CH$, and $>CH$ (aromatic) groups and α, β, γ, and δ are the values, respectively, of the absorptive index for a unit group. The formula is demonstrated to hold, with modifications, for paraffins, cycloparaffins (naphthenes) and aromatic hydrocarbons, including 10 of high molecular weight (C_{24} to C_{32}). The accuracy of the method, as well as restrictions on its application are given, and its use is demonstrated by an example of the identification of the number of $-CH_3$, $>CH_2$, and $\geqslant CH$ groups in an unknown branched-chain paraffin hydrocarbon. (*Author's Abstract.*)

A. R. GLASGOW, JR., and S. T. SCHICKTANZ: *A study of ball packings for laboratory rectifying columns.*—The efficiency, liquid hold-up, and surface area of packings composed of glass balls 2.95 and 3.80 mm in diameter, lead balls 2.05 and 4.05 mm in diameter, and copper balls 4.00 mm in diameter, have been determined. The description and operation of the glass experimental column are given. For a column 2.6 cm in diameter packed with balls 0.2 to 0.4 cm in diameter, it is found that: (1) the heat conductivity and the nature of the material of the packing have no effect on the efficiency of separation, liquid hold-up, or through-put of the still; (2) the efficiency is substantially in direct proportion to the total surface area exposed in the

packed column, and approximately linear with the reciprocal of the diameter of the balls; and (3) the hold-up is approximately linear with the total surface area. (*Authors' Abstract.*)

R. E. GIBSON: *The Hoffmeister series of anions and cations, and some thermodynamic properties of solutions.*

495TH MEETING

The 495th meeting was held in the auditorium of the Cosmos Club on Thursday, November 11, 1937, President NICOLET presiding.

The program was preceded by the annual elections of officers for the ensuing year. The following were elected: *President:* NATHAN L. DRAKE, University of Maryland; *Secretary:* FRANK C. KRACEK, Geophysical Laboratory; *Treasurer:* RAYMOND M. HANN, National Institute of Health; *Councilors:* L. B. BROUGHTON, V. DU VIGNEAUD, R. E. GIBSON, H. T. HERRICK, G. E. F. LUNDELL, Ben H. NICOLET; *Board of Managers:* NORMAN BEKKEDAHL, H. L. HALLER, M. M. HARING, S. B. HENRDICKS, E. R. SMITH, K. T. WILLIAMS

The Society was addressed by FRANK C. WHITMORE, President-Elect of the American Chemical Society and Dean of the School of Chemistry and Physics of the Pennsylvania State College, upon the subject of *Hydrocarbons.* The speaker discussed in considerable detail the research and economic aspects of hydrocarbon chemistry, stressing particularly the relation of these compounds to current trends in organic chemistry in general.

496TH MEETING

The 496th meeting was held in the auditorium of the Cosmos Club on Thursday, December 9, 1937, President NICOLET presiding.

The Society was addressed by HERBERT J. WOLLNER, Consulting Chemist to the Secretary of the Treasury on the subject of *the denaturation of industrial alcohol.* The speaker explained some of the problems encountered in the rapidly increasing use of alcohol by the expanding chemical industry, both from the standpoint of legitimate use and from the standpoint of preventing illegal diversion of the article for non-industrial uses. More and more exacting demands on specification, resulting from greater chemical control of ultimate products, require the continual modification of denaturing formulas to suit the requirements of processing. An extensive survey has been completed on all the industrial uses of alcohol in the United States. This survey has been paralleled by laboratory studies of the behavior of denaturants. The results of this study and survey direct the attention to that particular group of aliphatic compounds which contain oxygen atoms as providing the greatest promise for denaturants to meet industrial requirements. In this group are the ketones, higher alcohols, and ethers.

497TH MEETING

The 497th meeting, which also was the 54th annual meeting of the Society, and the 44th annual meeting of the Society as the Washington section of the American Chemical Society, was held in the Auditorium of the Cosmos Club on Thursday, January 13, 1938, with President DRAKE in the chair.

The first part of the meeting was devoted to the annual reports of the officers. The Secretary reported that the Society had 611 members on December 1, 1937. Of these, 5.4 per cent were in arrears. During 1937 the Society lost 51 members by removal, resignation and deaths, and gained

109, the net gain being 58. The following members died during the year: LOUIS W. MATTERN, ALFRED OBERLE. Eight regular meetings were held during the year, with an average attendance 157, or 27.2 per cent of the paid up membership. Percentage attendance for all the years of the Society's existence is 27.1. The HILLEBRAND PRIZE for 1936 was awarded to VINCENT DU VIGNEAUD, Professor of Biochemistry at the George Washington University School of Medicine in recognition of his work on *the biologically important compounds of sulfur*. The award was presented to the recipient at the annual dinner of the Society, held in March. The previous recipients of the PRIZE, and the subjects of the award, published here for the first time, were:

1925: RICHARD F. JACKSON, on *Levulose*.
1926: GEORGE W. MOREY, on *Constitution of Glass*
1927: EDWARD P. BARTLETT, on the *Gas Laws at high Temperatures and Pressures*.
1928: JAMES H. HIBBEN, on *Radiation and Collision in Chemical Gas Reactions*
1930: CLAUDE S. HUDSON, on the *Ring Structure of the Sugars*.
1931: G. E. F. LUNDELL, on the book, *Applied Inorganic Analysis*, by Hillebrand and Lundell.
1932: F. B. LAFORGE and H. L. J. HALLER, on the *Structure of Rotenone*.
1933: EDWARD W. WASHBURN, posthumously, on the *Electrolytic method of Separation of the Isotopes of Hydrogen*.
1934: FREDERICK D. ROSSINI, on the *Thermochemistry of the normal aliphatic Hydrocarbons and alcohols*.
1935: OLIVER R. WULF, on the *Chemistry of the earth's Atmosphere in its Relation to absorbed Solar Radiation*, and on his work on *Infrared absorption Spectra*.

The treasurer reported receipts $656.22, expenditures $534.74, unexpended balance, $121.48. Total resources, as of December 31, 1937: $5,423.98. The auditing committee (A. R. MERZ, Chairman, P. H. GROGGINS, WM. H. ROSS) had examined the books and had found them to be in order.

The following committees were appointed to serve during 1938: *Communications:* G. E. HILBERT, Chairman, J. F. SCHAIRER, H. P. NEWTON, S. B. HENDRICKS, N. K. RICHTMYER, H. S. ISBELL. *Entertainment:* E. R. SMITH, Chairman, L. W. BUTZ, K. T. WILLIAMS, A. L. PITMAN, STEPHEN BRUNAUER, L. A. SHINN, C. M. SMITH, FLORENCE KING, D. READY, E. M. NELSON, J. J. FAHEY, N. K. RICHTMYER, C. E. WHITE, *Membership:* M. M. HARING, Chairman, F. E. ALLISON, E. O. HAENNI, W. J. HAMER, H. M. HARSHAW, H. S. ISBELL, JAMES MCLAREN, J. H. ROE, J. R. SPIES, F. P. VEITCH, JR. *Budget:* J. F. COUCH, Chairman, H. T. HERRICK, C. W. WHITTAKER. *Finance and Investment:* EDWARD WICHERS, M. X. SULLIVAN, A. K. BALLS.

After the presentation and acceptance of the reports, the Society was addressed by the retiring PRESIDENT, BEN H. NICOLET, on *Biochemistry by Analogy: The Sulfur of Cystine*. (Published in THIS JOURNAL, page 84.)

FRANK C. KRACEK, *Secretary*.

Obituary

JOHN NAPOLEON BRINTON HEWITT, ethnologist, Bureau of American Ethnology, Smithsonian Institution, died at his home in Washington, D. C., October 14, 1937. In his death there passed from the field of anthropology the last of that notable group of students of the American Indian which Major J. W. Powell assembled when he founded the Bureau of American Ethnology. Mr. Hewitt was born in the neighborhood of Lewiston, Niagara Co., N. Y., Dec. 16, 1859. His mother, Harriet Brinton (Hewitt), was of French, English, and Tuscarora Indian descent and his father was a Scotch physician. Young Hewitt received his early education in the public schools of Niagara County, and later pursued classical courses in Wilson Union and Lockport Union academies. His field studies began in 1879, when, as assistant to Mrs. Erminnie A. Smith, ethnologist, he was engaged for seven years in investigating the language mythology, and social organization of the Tuscarora and Onondaga Indians. In 1886 he was called to the Bureau of American Ethnology where he continued in this line of research to the end of his life, soon coming to be regarded as the leading authority on the organization of the Iroquois League and the ceremonials, customs, and usages of the tribes composing it. He acquired an intimate knowledge of the languages of the League, including a speaking knowledge of Mohawk and Onondaga, and also became acquainted with several Algonquian dialects.

During the later years of his active life Mr. Hewitt collected some material in the Chippewa, Ottawa, and Delaware dialects of Algonquian, but most of his personal investigations were devoted to the Iroquois and their immediate relatives. He was painstakingly conscientious in his work but it moved so slowly that only a small part was actually printed. In the manuscript collections of the Bureau there are over 250 entries under his name including nearly 8000 manuscript pages and 10,000 cards, over half under the heading Onondaga, but with considerable bodies of Mohawk, Tuscarora, and Seneca material. He edited the narratives of Denig and Kurz, early explorers among the western Indians. These were published by the Bureau in 1930 and 1937. Much of Mr. Hewitt's time was also devoted to the preparation of articles for the Handbook of the American Indians, edited by Mr. F. W. Hodge, Ethnologist-in-Charge, well over a hundred having been contributed by him. On March 19, 1918, Mr. Hewitt was appointed a member of the U. S. Board on Geographical Names and continued in that capacity until his death. He was a founder of the American Anthropological Association and a member of the Anthropological Society of Washington, which he served as treasurer from 1911 to 1926, and as President from 1932 to 1934. He was a member of the Washington Academy of Sciences.